Energy turnaround and consequences for conventional power stations

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Director Energy Technologies

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STEAG corporate profile

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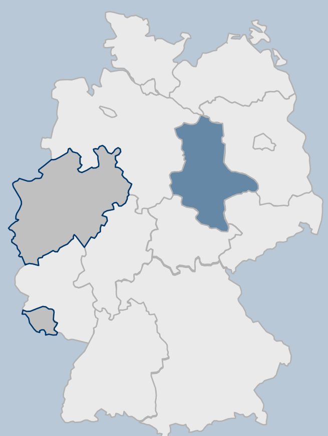
STEAG GmbH

Power Germany
Domestic power plants



Employees: 2,193
Sales: € 1,591 million

Power International
Power plants abroad

Employees: 692
Sales: € 558 million

Service Companies

- **STEAG Fernwärme GmbH**
- **STEAG Energy Services GmbH**
- **STEAG New Energies GmbH**
- **STEAG Power Minerals GmbH**
- **STEAG Technischer Service GmbH**

Employees: 3,129
Sales: € 657.5 million

Employees, total:	6,014
Sales / EBITDA:	€ 2.8 billion / € 385 million
Investment:	€ 261.9 million
Shareholders:	51 %: Consortium of seven municipal utilities from the Rhine/Ruhr region, 49 %: Evonik Industries
Installed capacity:	9,400 MW (7,700 in Germany / 1,700 abroad)
Electricity output:	38,096 GWh

Figures: Fiscal year 2012

Steag Power plant sites
A dependable energy expert for 75 years

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Bergkamen A 780 MW

Bergkamen

Bexbach 1 Weiher 1504 MW

Bexbach / Weiher

West 1 / 2 Voerde A/B 2234 MW

Voerde

Walsum 9/10 1200 MW

Duisburg

Herne 2/3/4 960 MW

Herne

Iskenderun 1/2 1,320 MW

Iskenderun

Raffineriekraftwerk 211 MW

Köln-Godorf

Raffineriekraftwerk 162 MW

Leuna

Lünen 6/7 507 MW

Lünen

Mindanao 1/2 232 MW

Mindanao

Termopaipa IV 165 MW

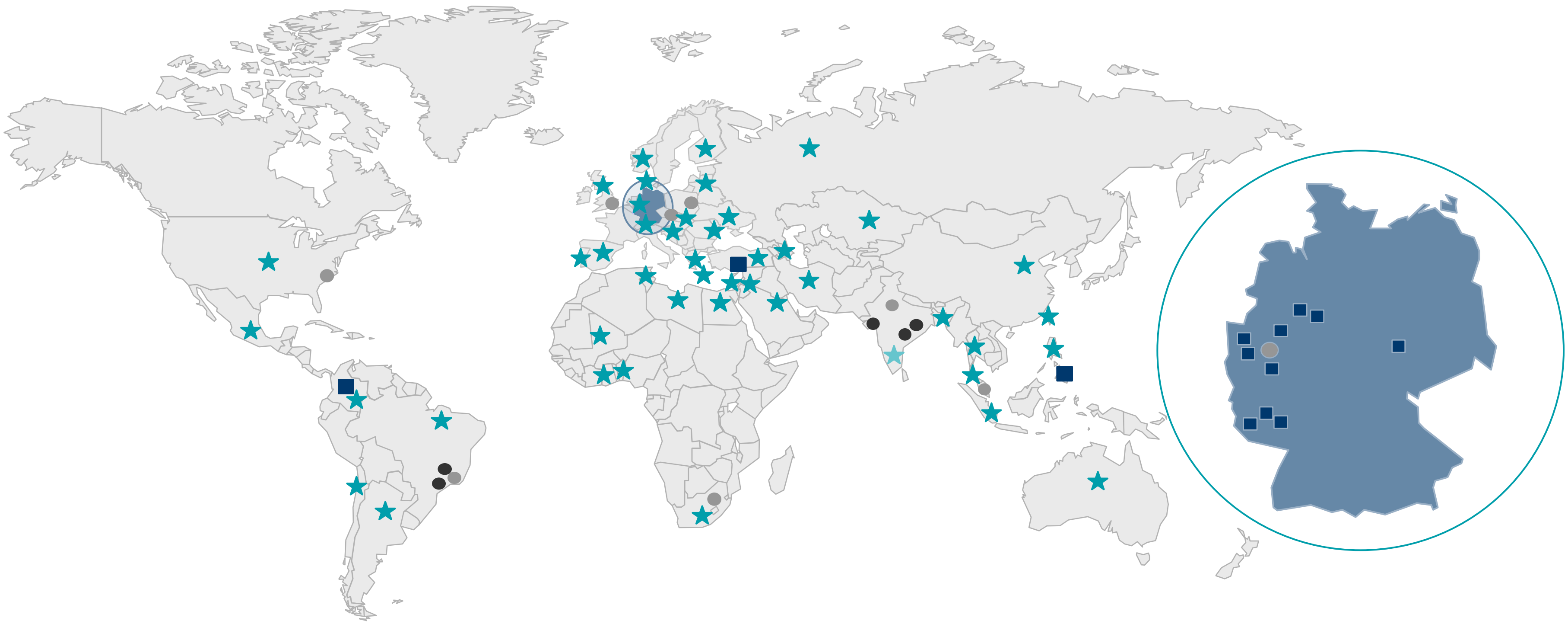
Paipa

MKV, HKV, MHK *) 466 MW

Völklingen-Fenne

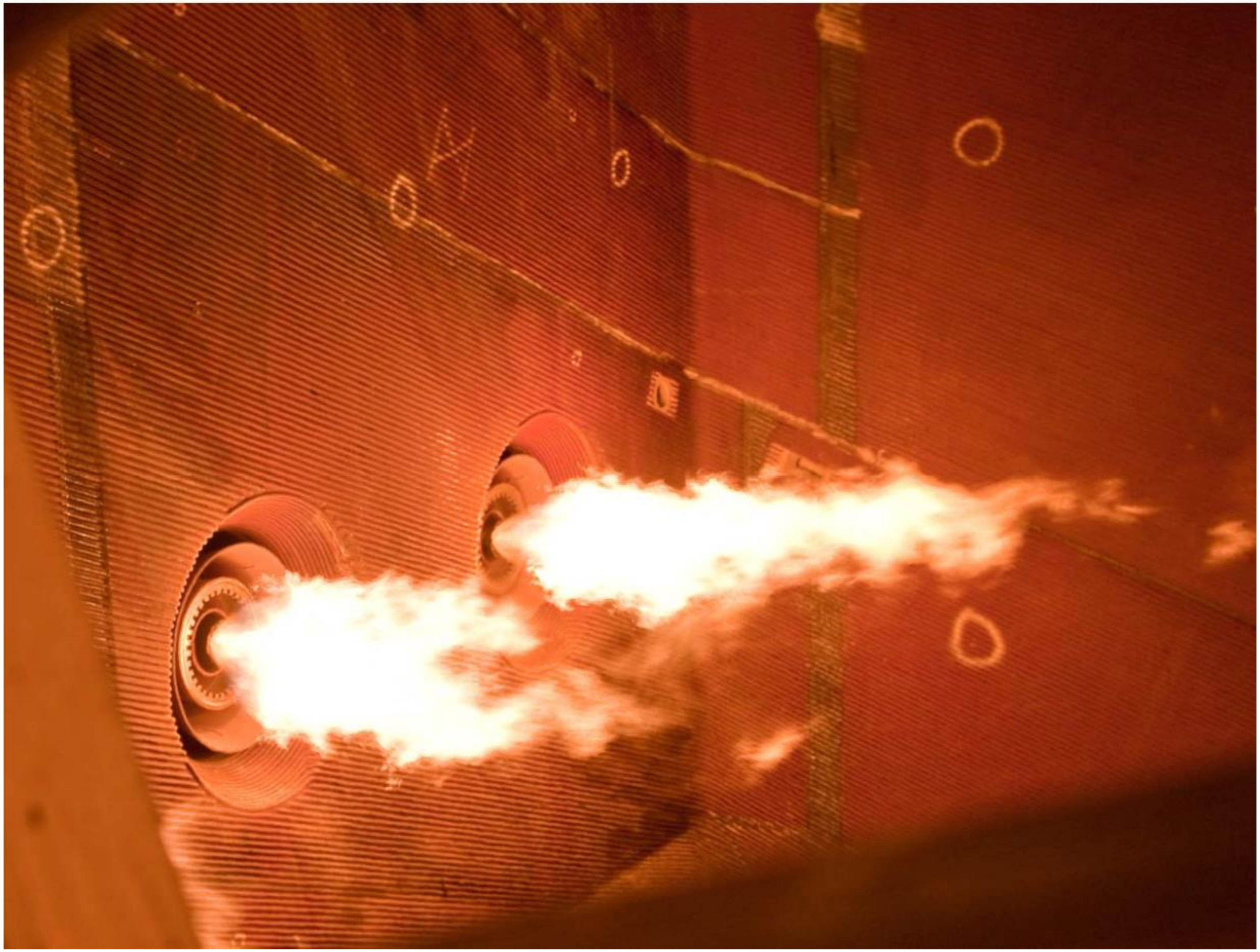
hard coal | coke oven gas | refinery by-products

STEAG can rely on global experience with its own engineers and power plants

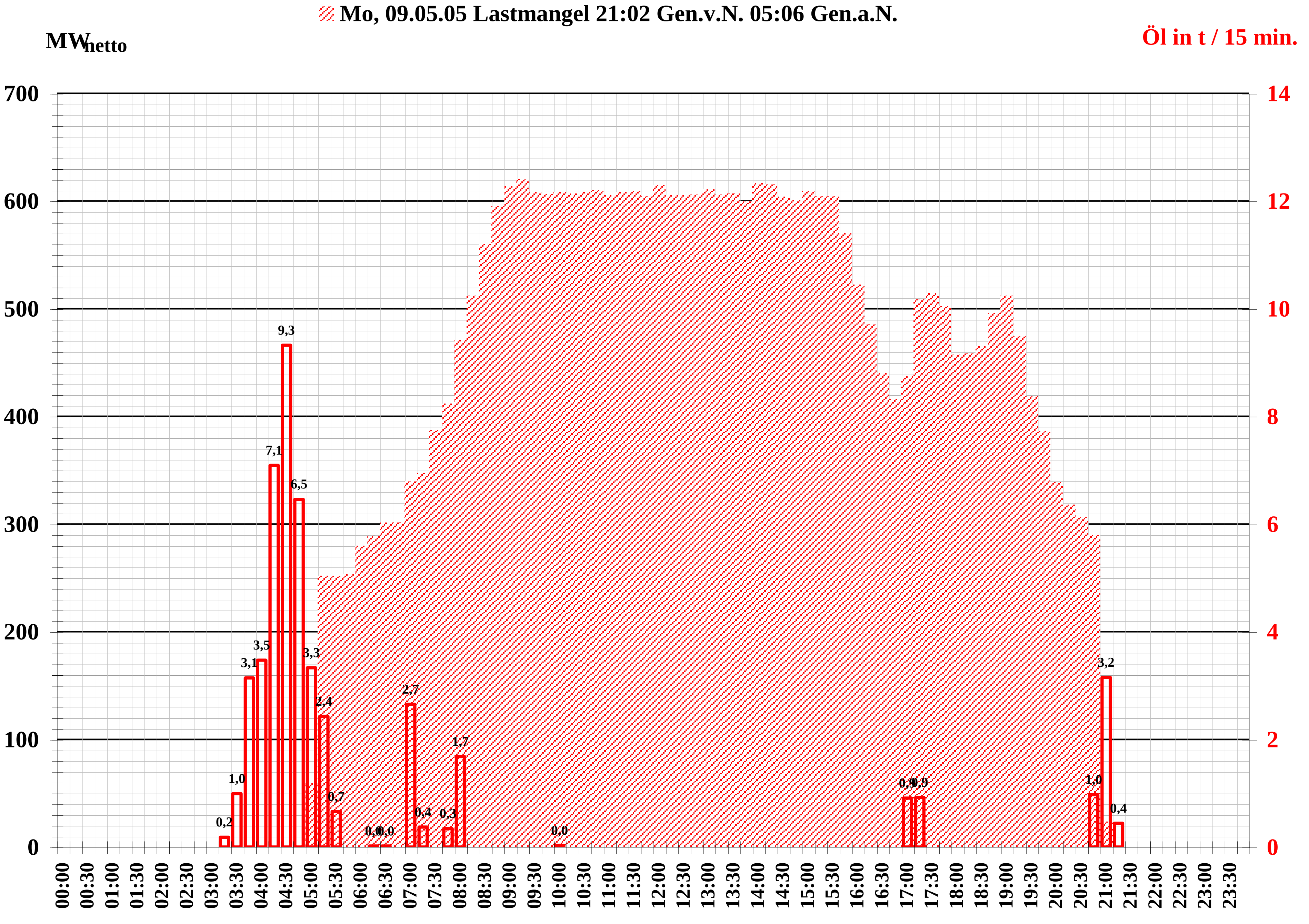


■ Power Plant Site ● O&M ● Präsence ★ Project Experience

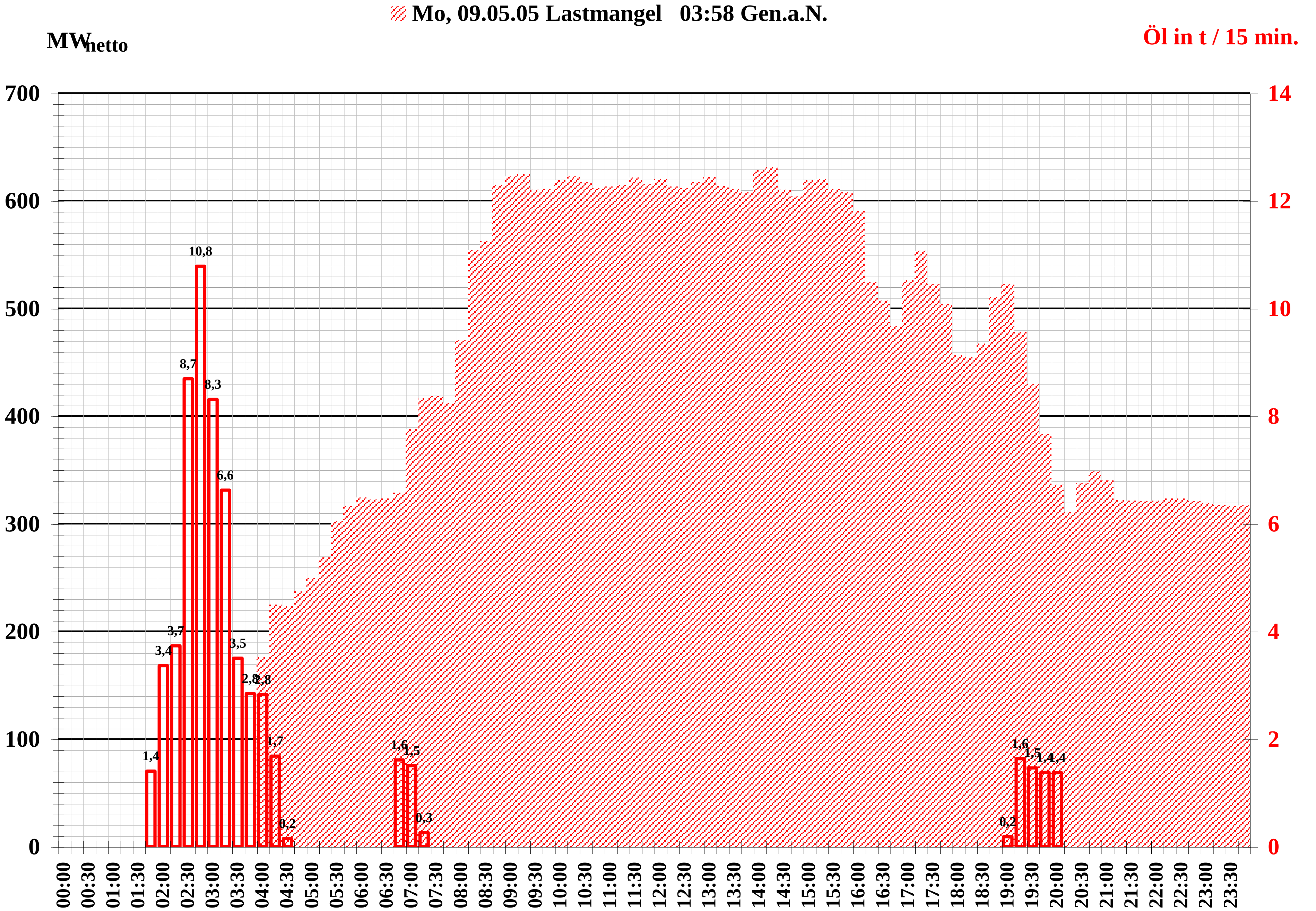
Oil fire
The kind of fire we try to minimize in a coal fired power plant



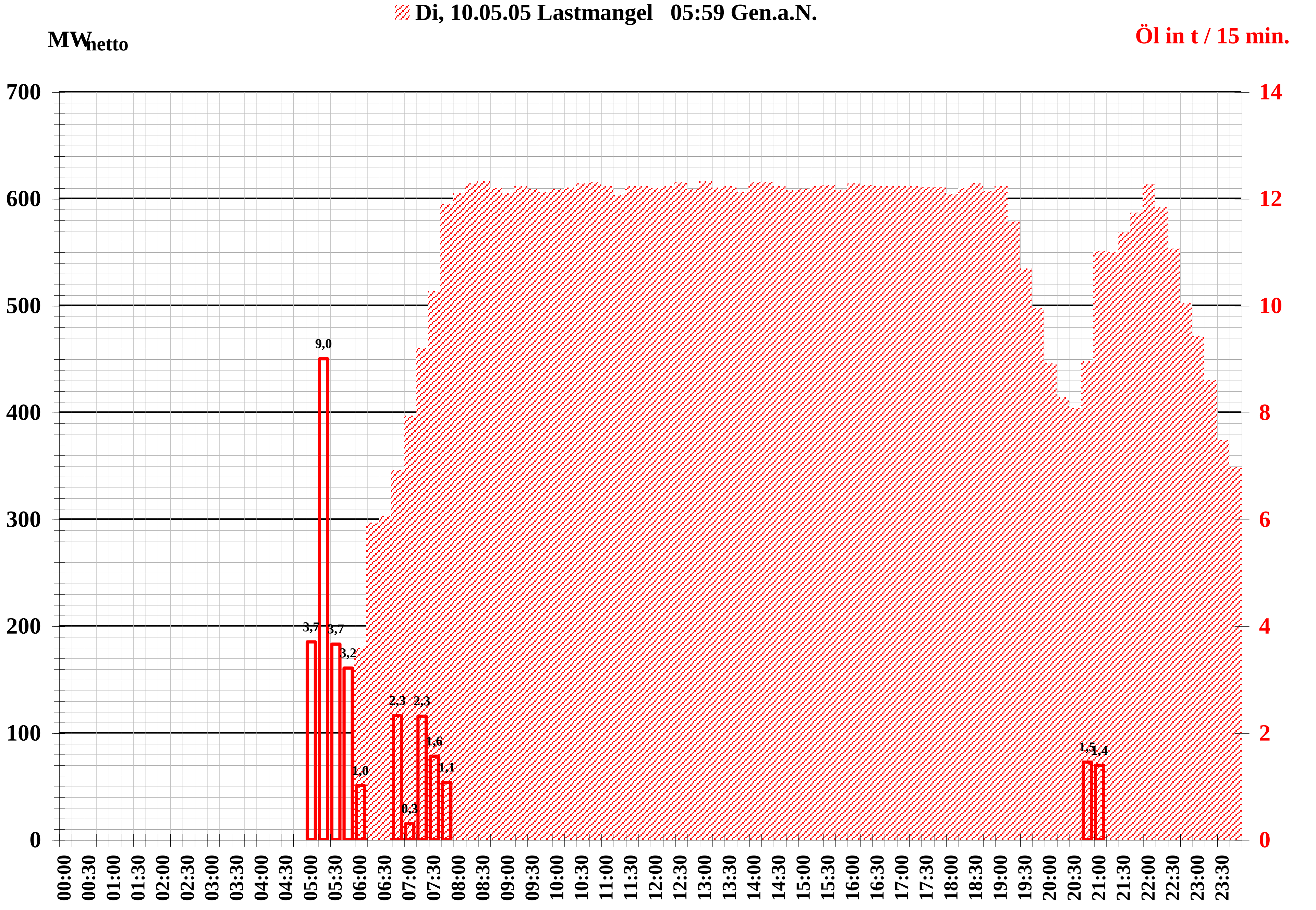
KW Voerde Block A



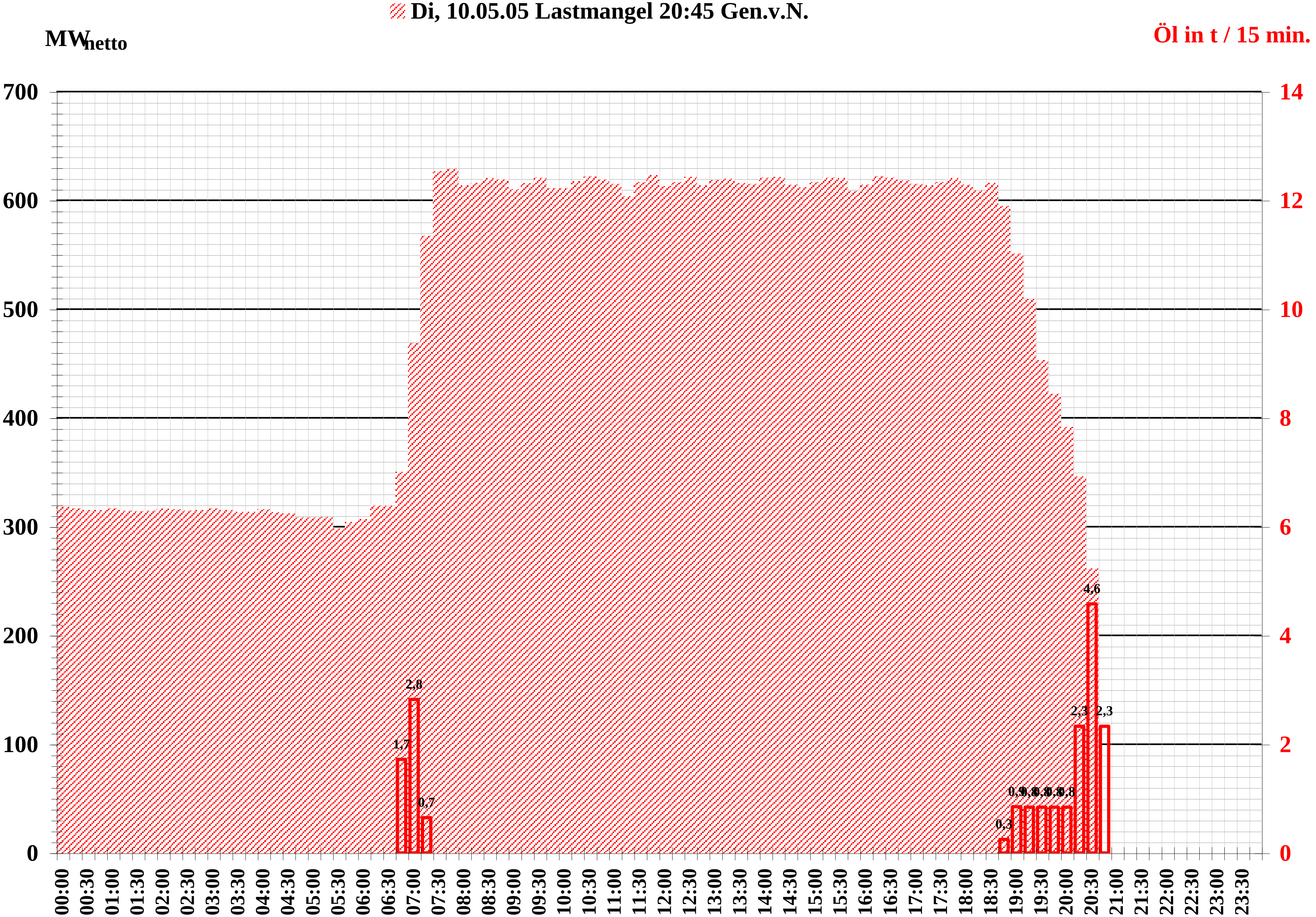
KW Voerde Block B



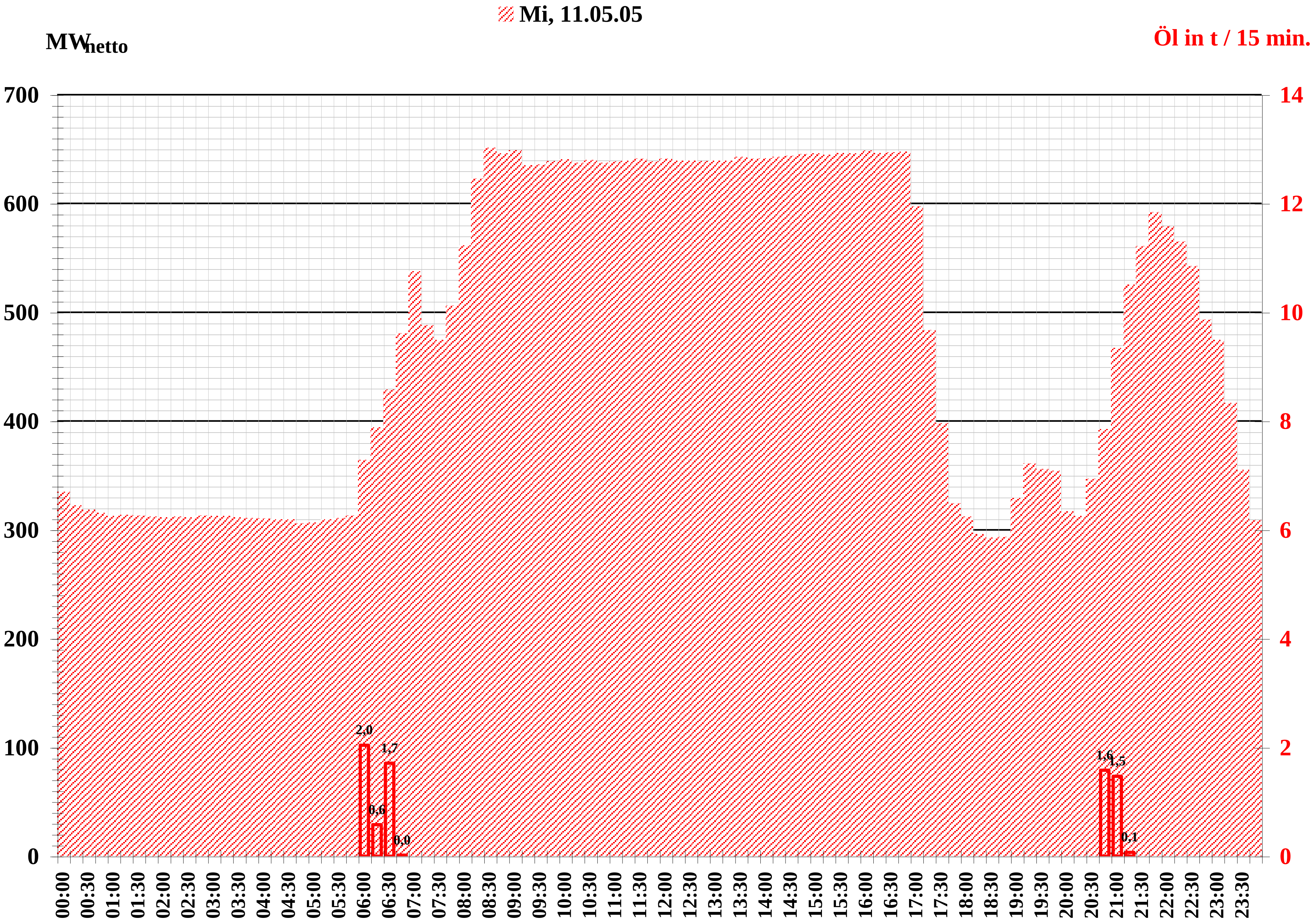
KW Voerde Block A



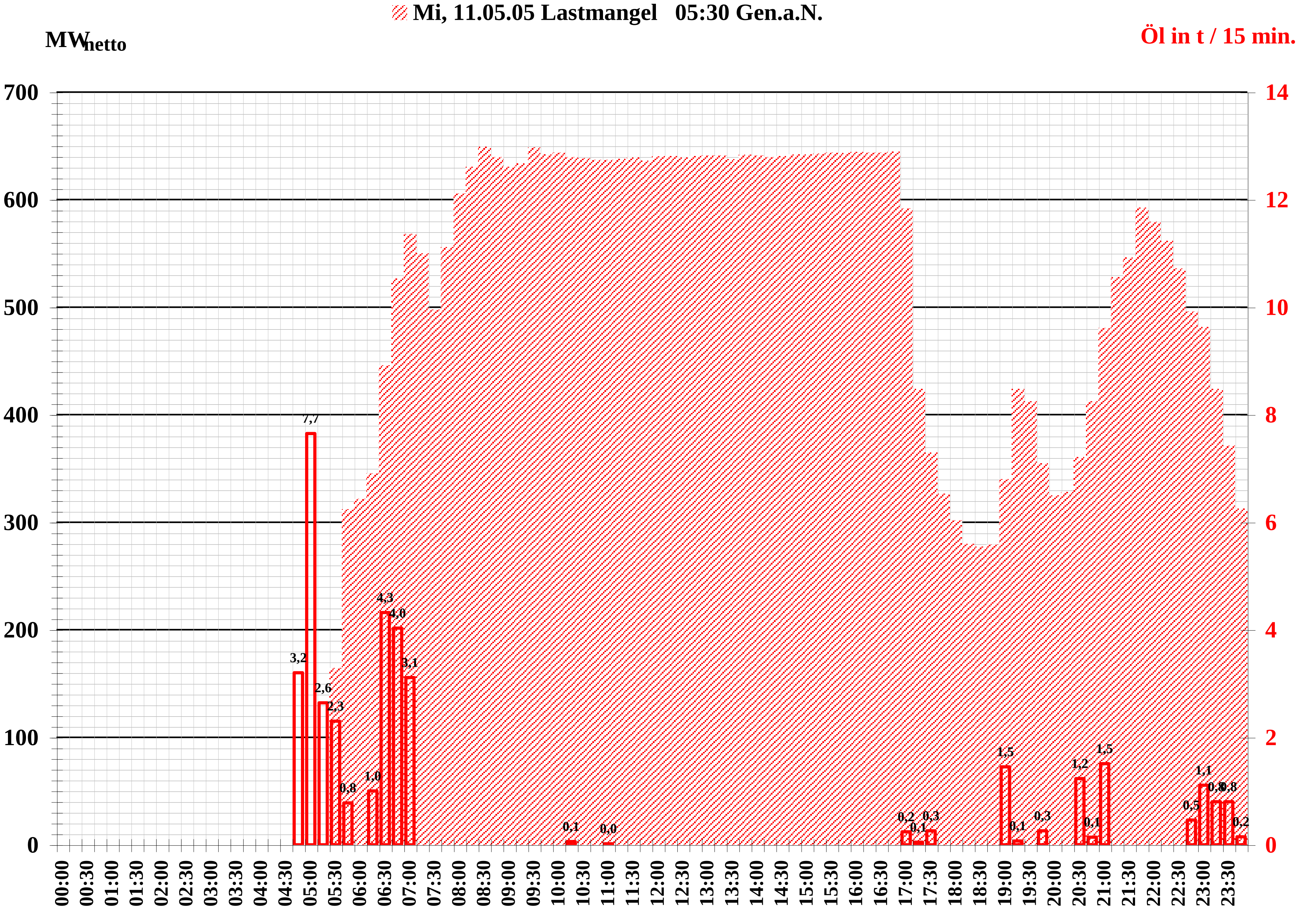
KW Voerde Block B



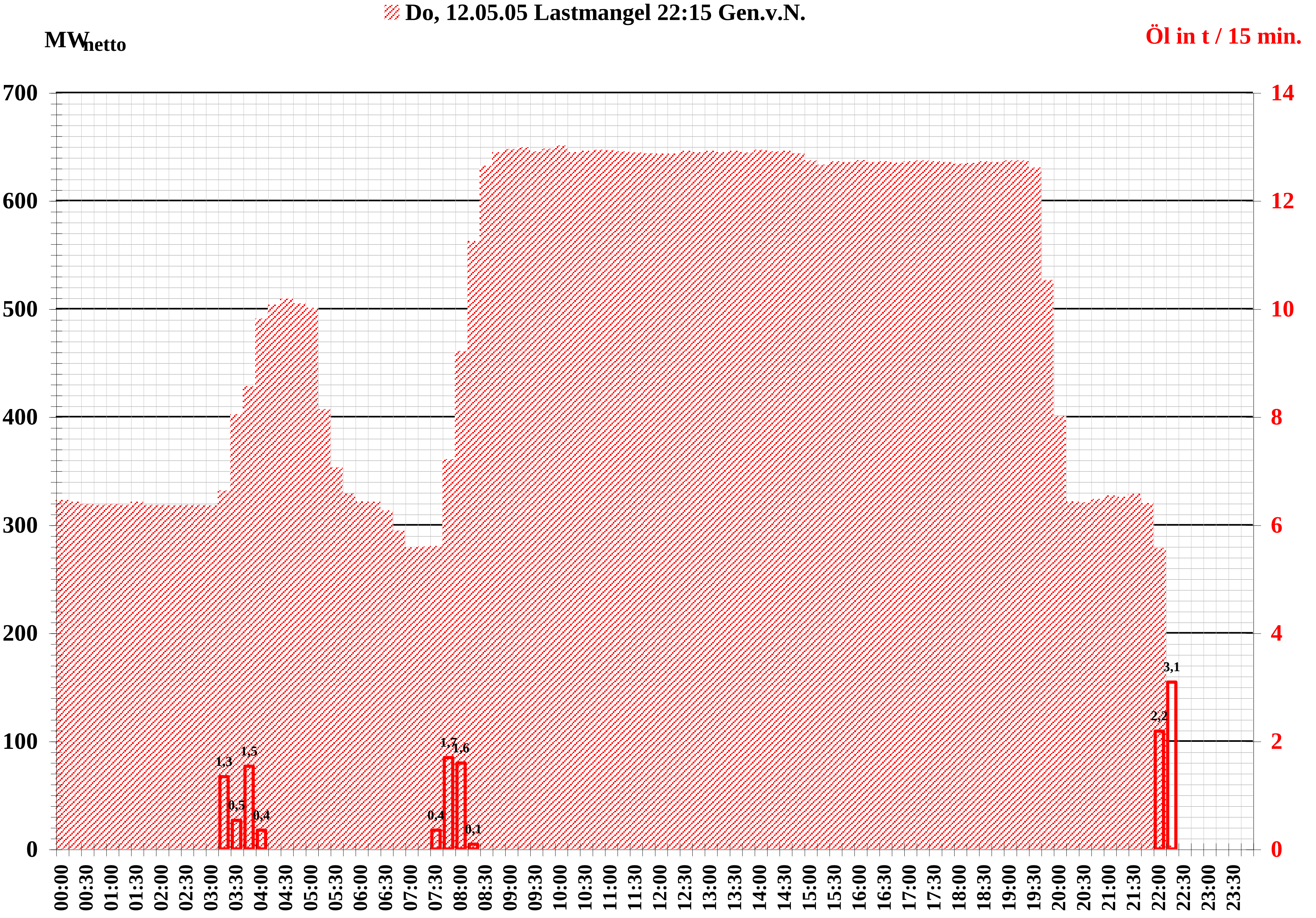
KW Voerde Block A



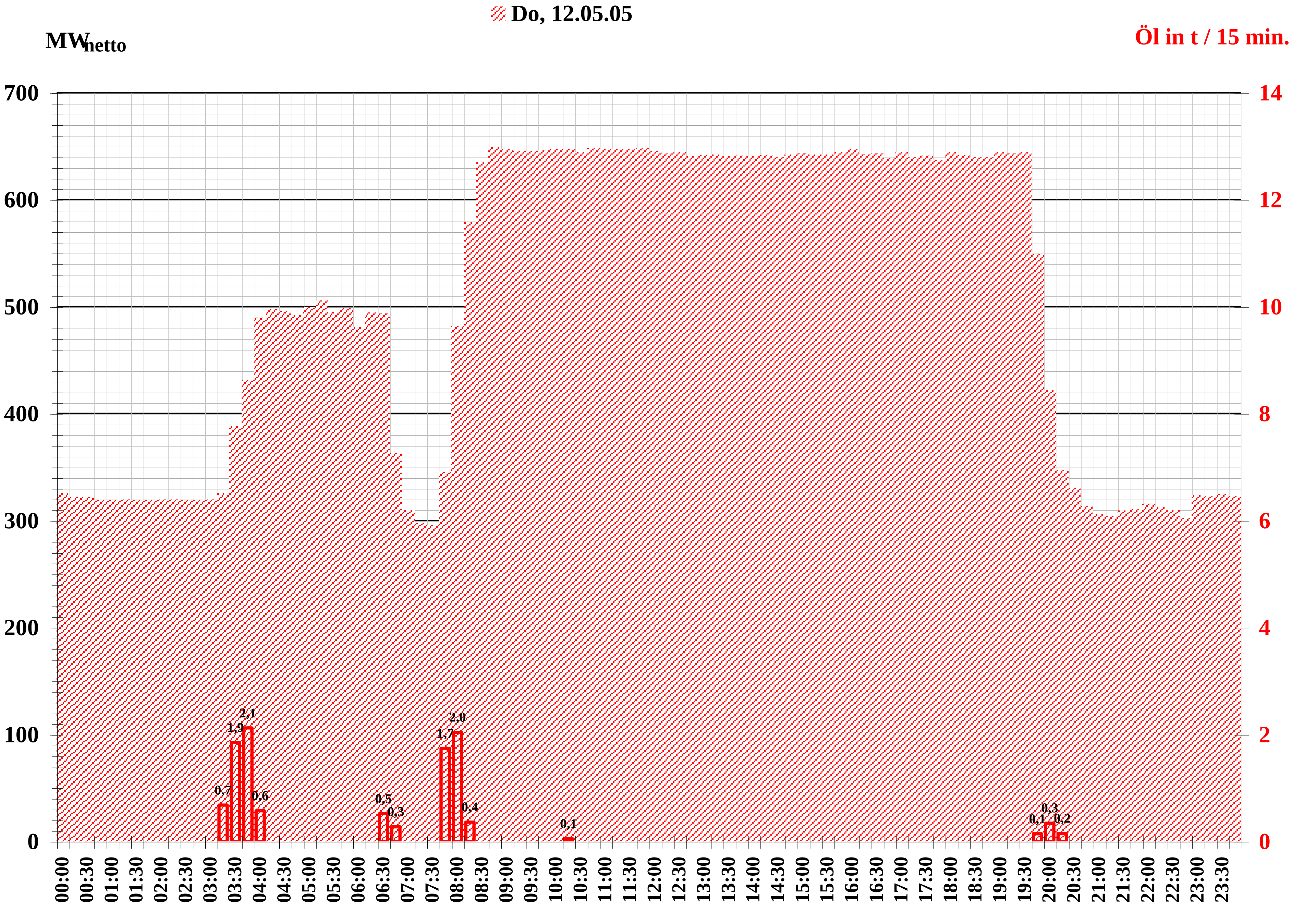
KW Voerde Block B



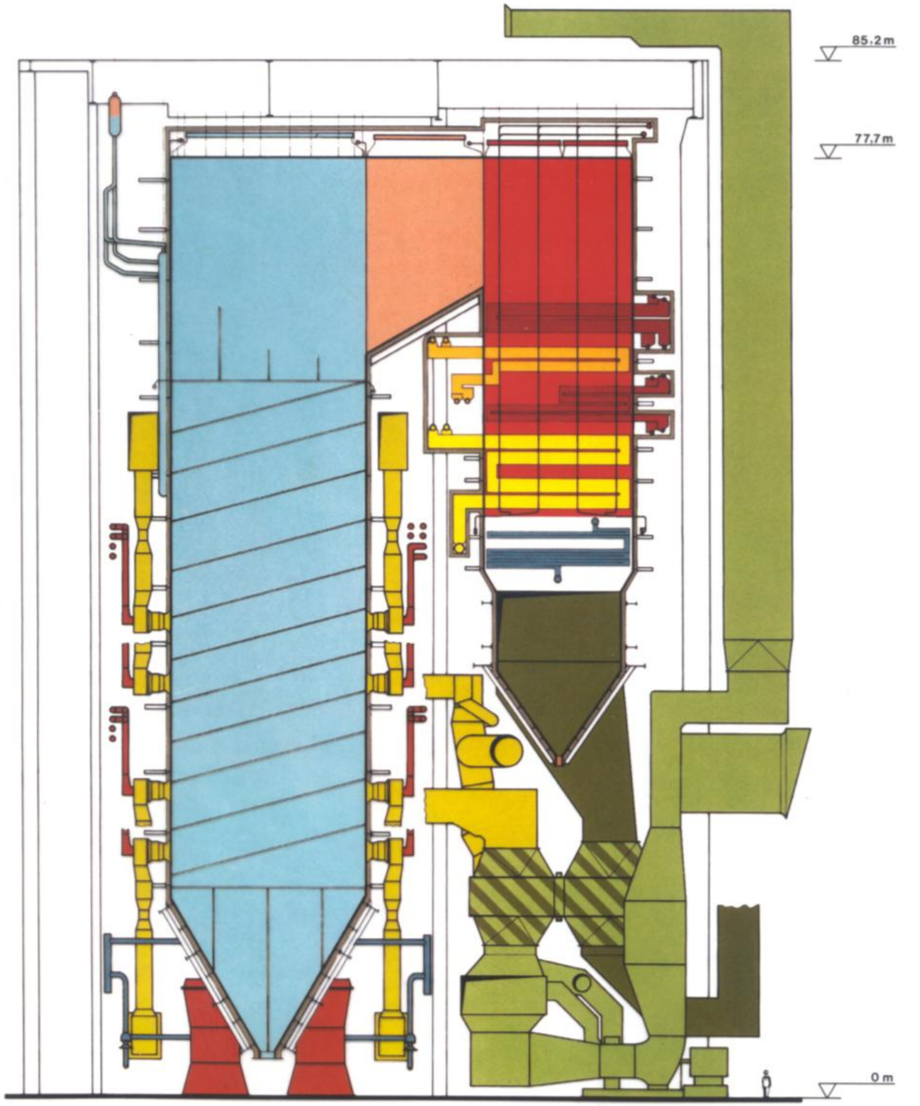
KW Voerde Block A



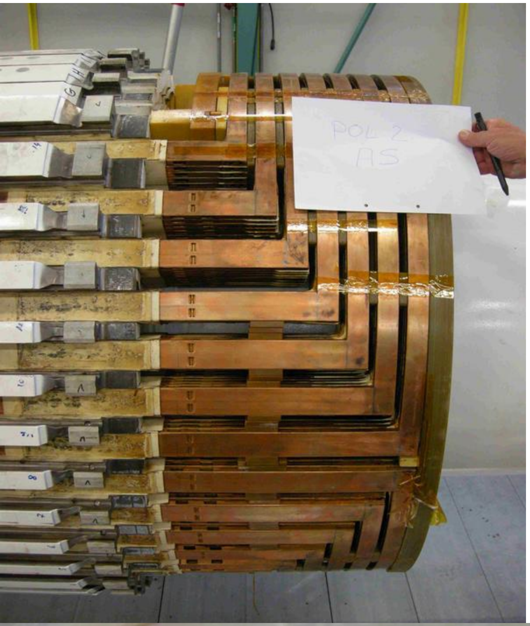
KW Voerde Block B

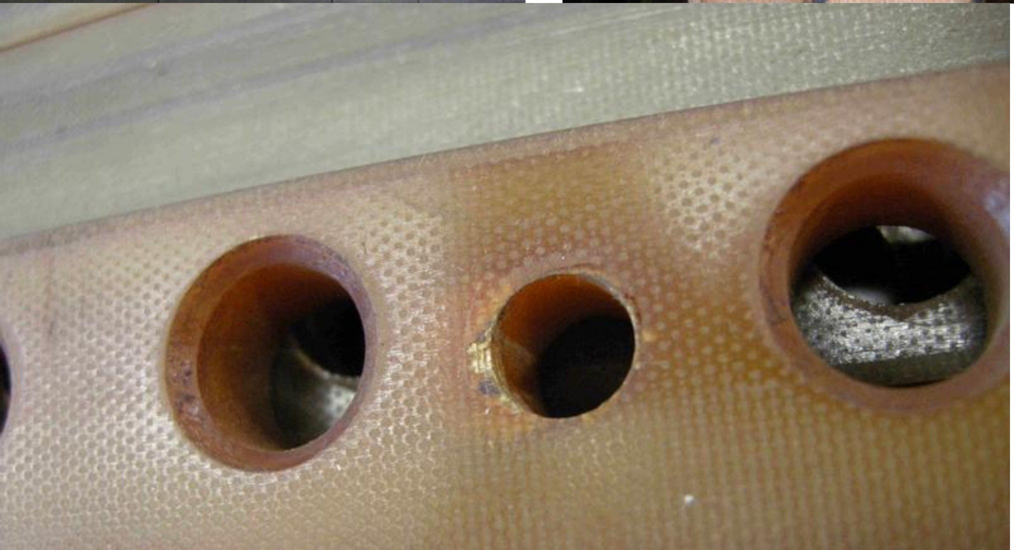


PP Voerde
761 MW units



PP Voerde
Generator rotor damages




What has changed in the German electricity market?

Yesterday

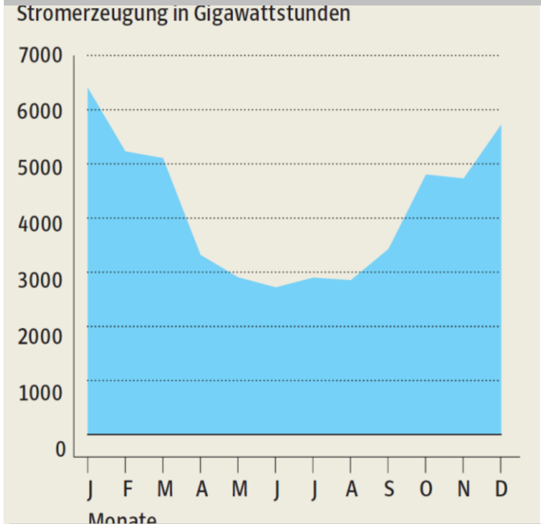
- Conventional, scheduled electricity generation centralized in load centers (coal, gas, nuclear and others)

Today

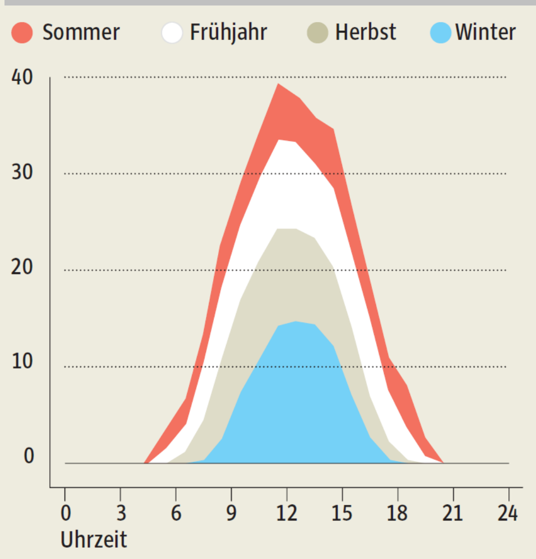
- Few or none scheduled conventional generation in load centers, Sometimes high wind and PV where generated when not needed (Solar mainly at noon, in summer more than in winter, Wind more in winter than in summer, heavy storm could be followed by calm periods)

- Partly far away from the load centers

Yearly Fluctuation of Wind in GWh



Daily Fluctuation of solar Power in % of installed



Renewables and coal fired power station – a team to adjust the volatile energy from wind

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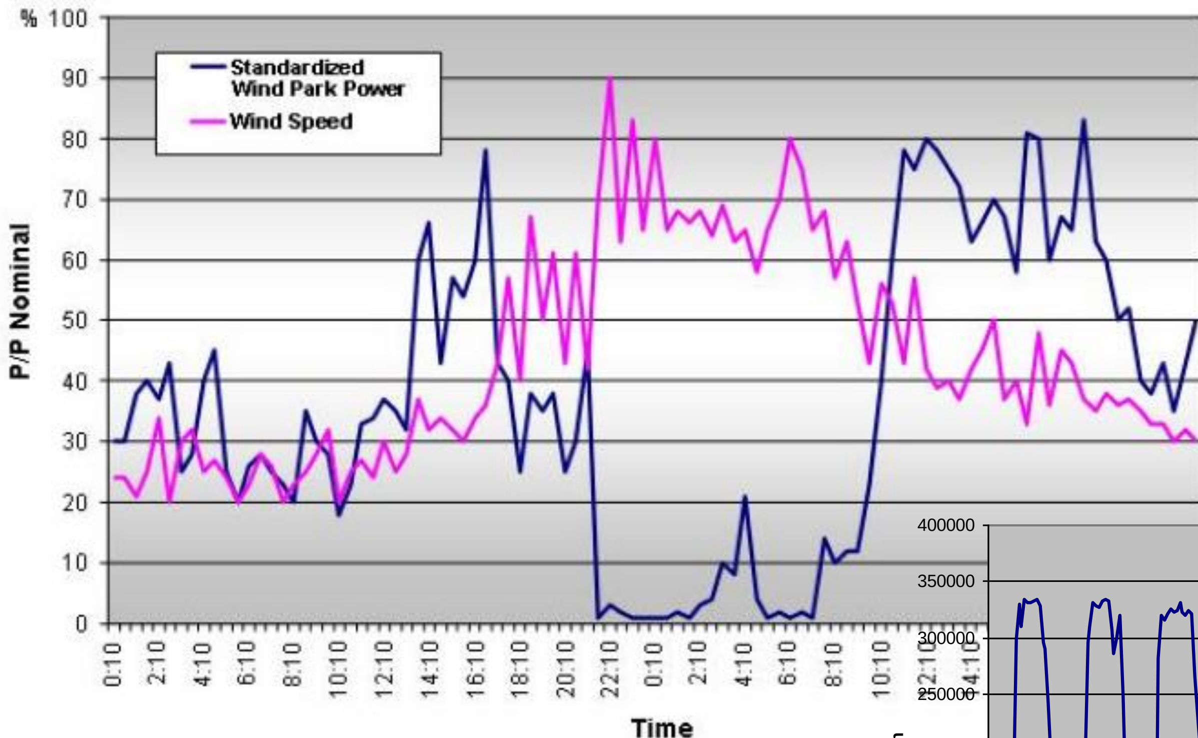
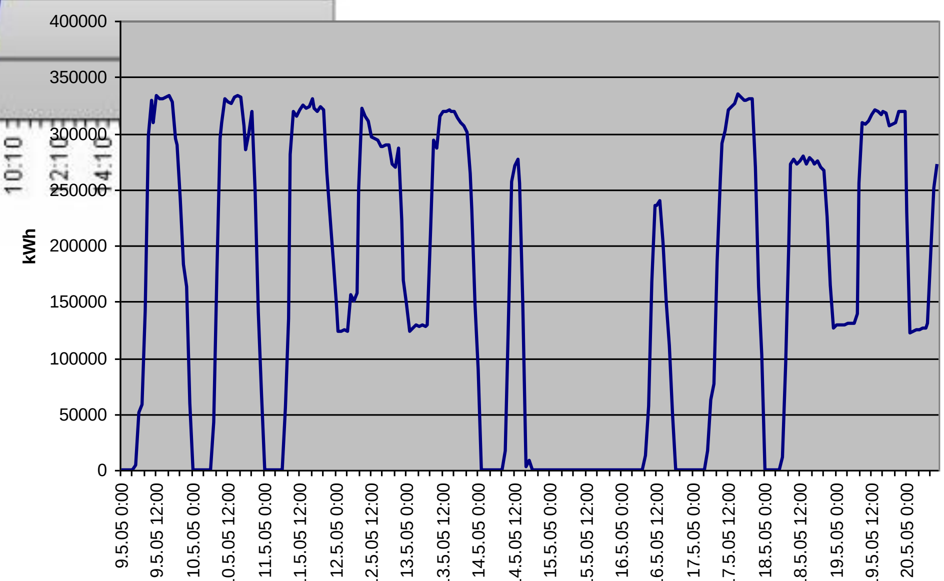


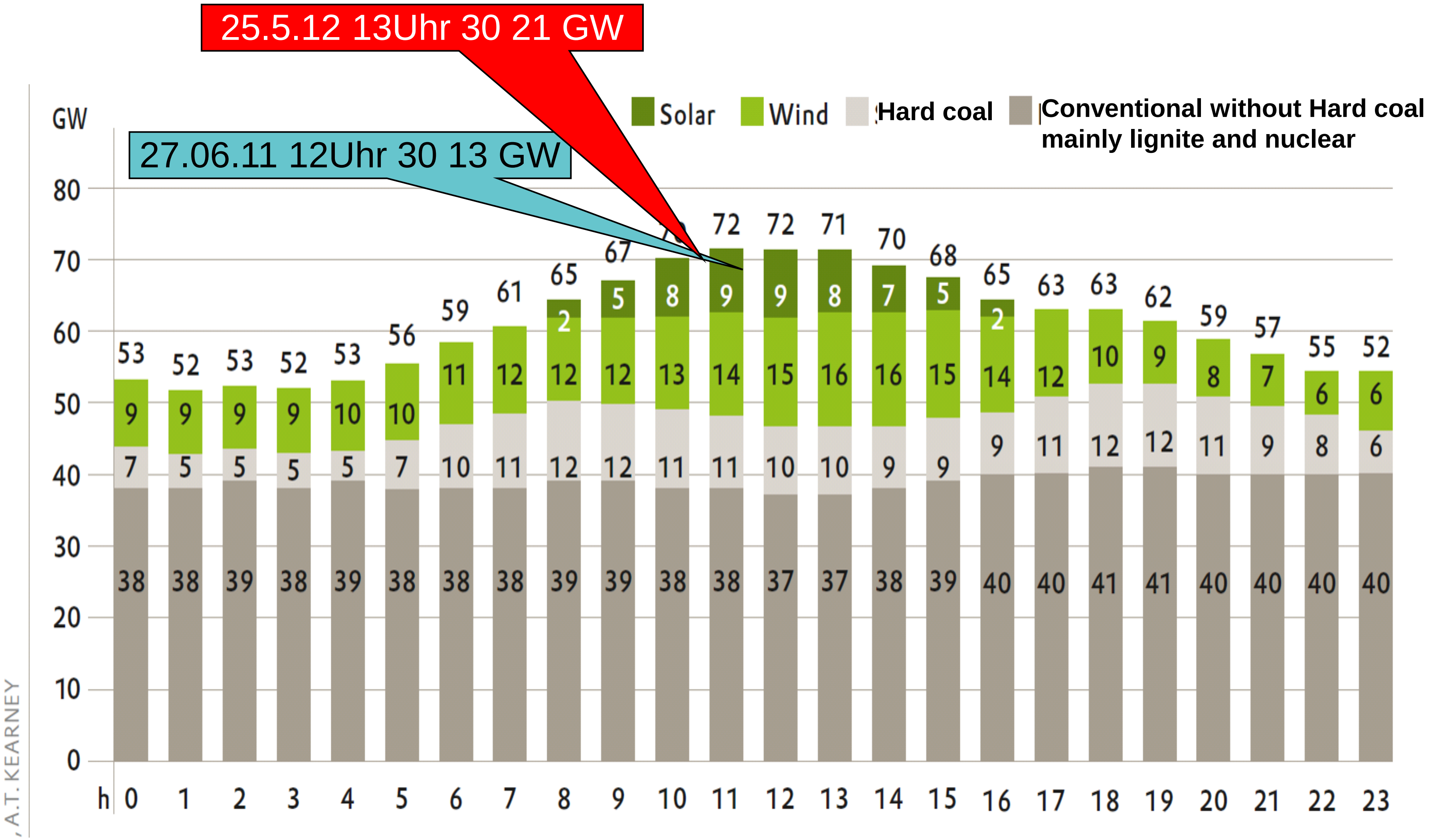
Daily start up and shut down of big coal fired power stations



Increase of fluctuating renewable energy sources as well as economical requests ask for higher flexibility of modern fossil fired steam power plants

Quelle: VGB Kongress 2007, Lambertz

Electricity generation in Germany on a typical day 9.3.2011– 27.6.11 – 25.5.12



Priority of renewables at the expense of hard coal fired power plants

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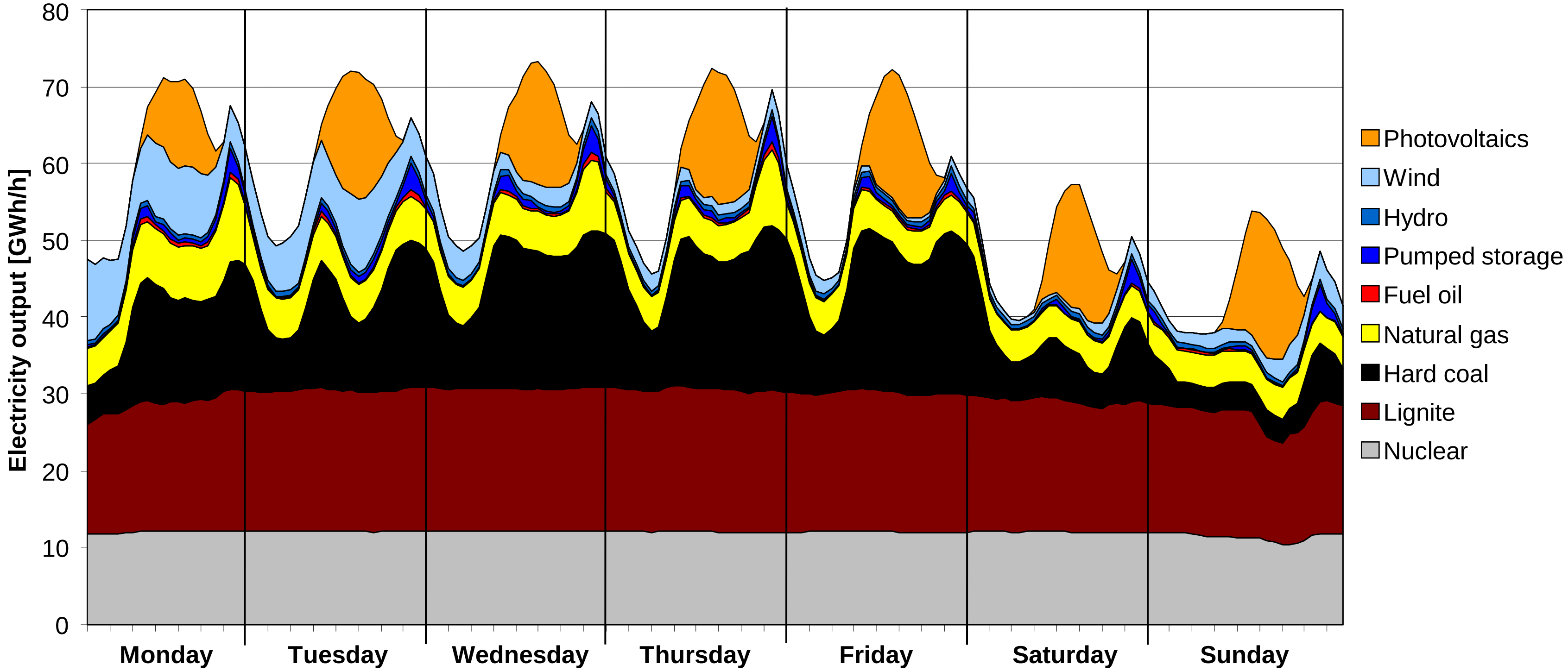
Electricity output during a typical week in spring 2012



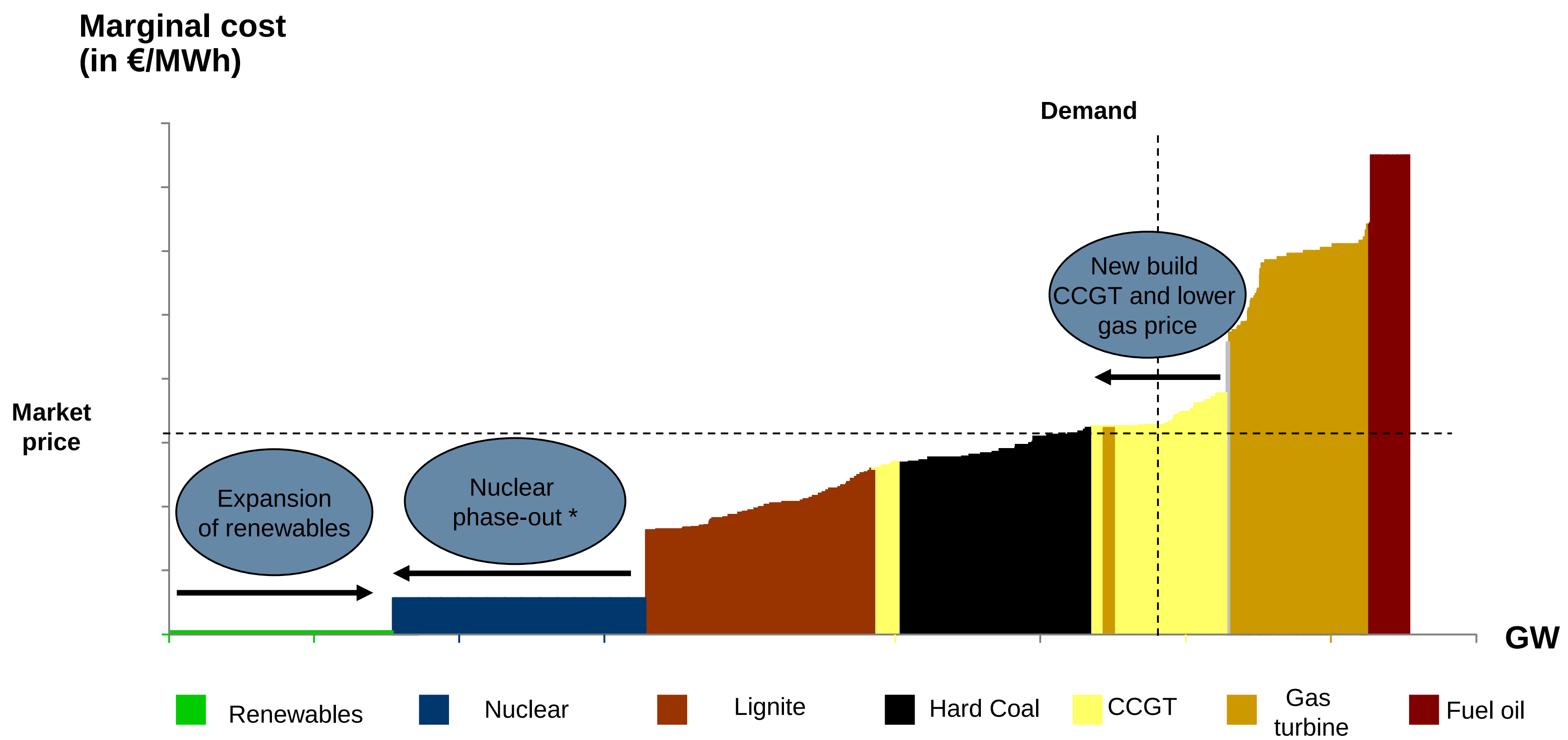
Consequences for short-notice dispatch of power plants:

- Several start-ups and shutdowns every day
- High load change rates
- Few hours of supply to the grid

Data source: Information provided on the EEX transparency platform

Merit order

The generating cost of the last power plant in the merit order needed to meet the maximum capacity demand at a time determines the market price



*without fuel-rod tax

→ Factors shifting the merit order curve to the left or to the right

Flexible operation

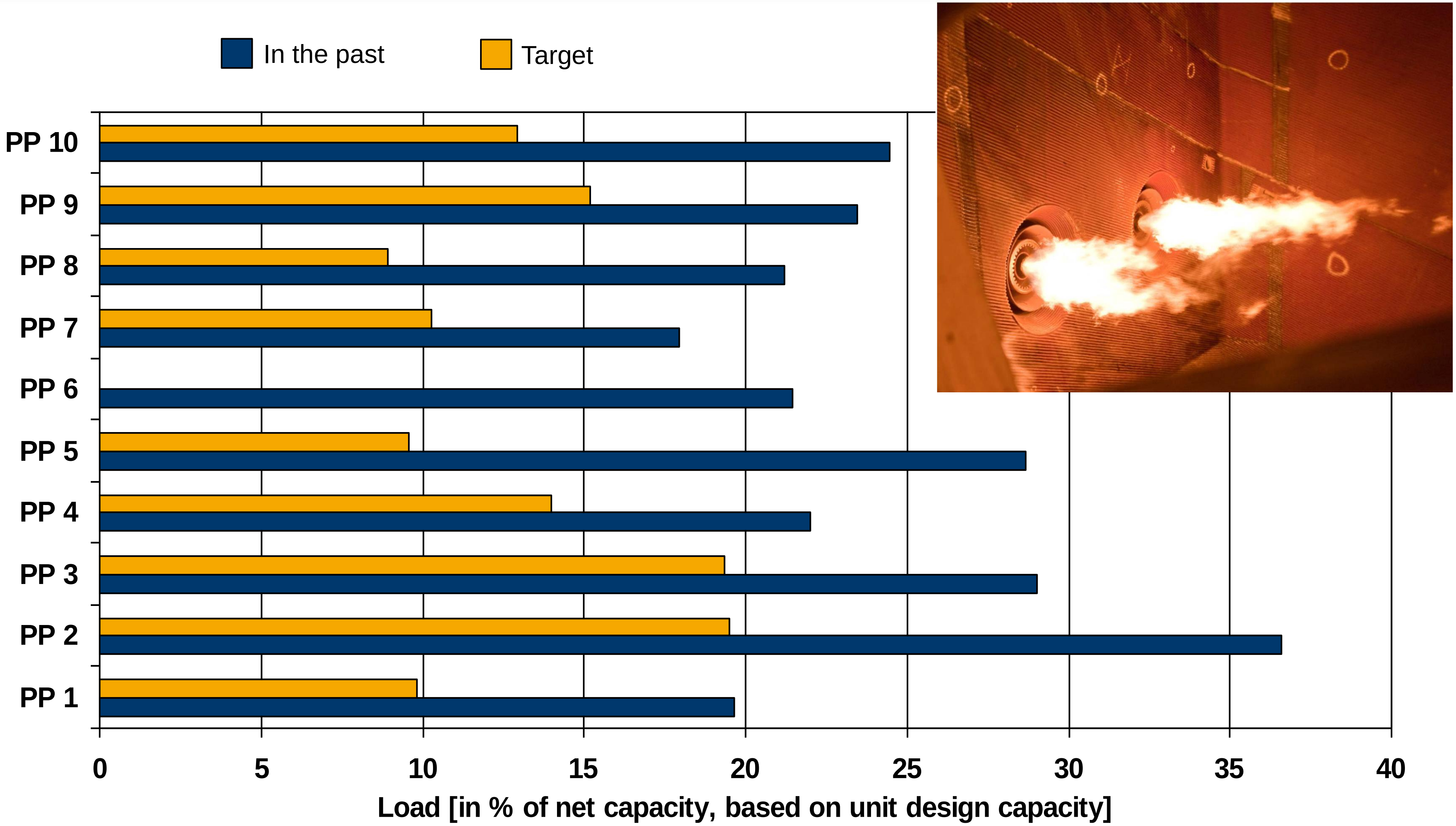
What are the goals?

1. **Increase the ramp rate**
2. **Reduce the part load in pure coal operation to avoid frequent start ups and shut downs**
3. **Avoid negative consequences for the entire power plant**

What are the topics?

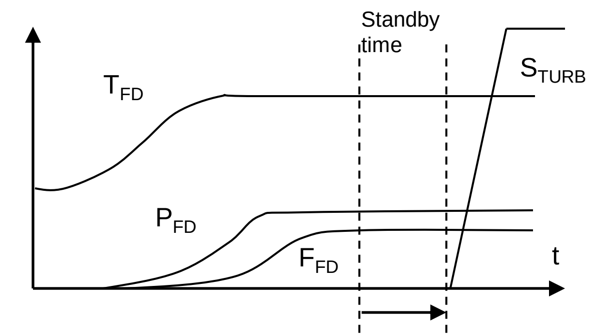
- **Coal Storage**
- **Combustion system**
- **Water Steam Cycle**
- **DeNOx-Plant**
- **ESP**
- **Flue Gas Desulphurization**
- **Stack**

Reduction of minimum load

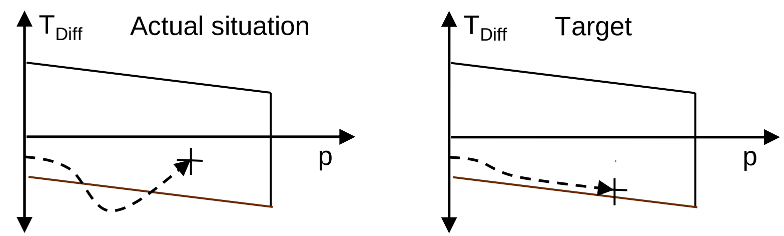


Optimization of start-up

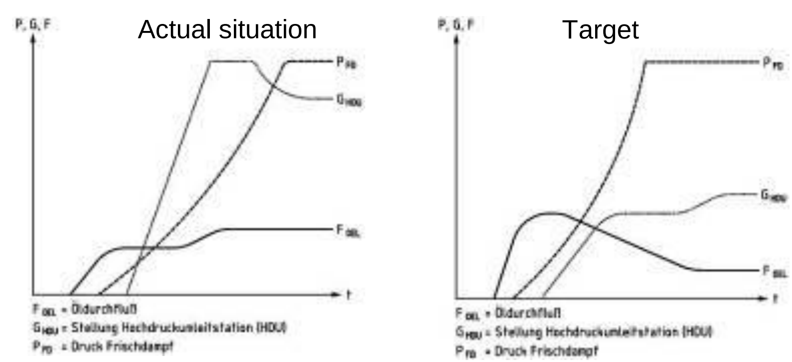
- **Start-up "to the point"**



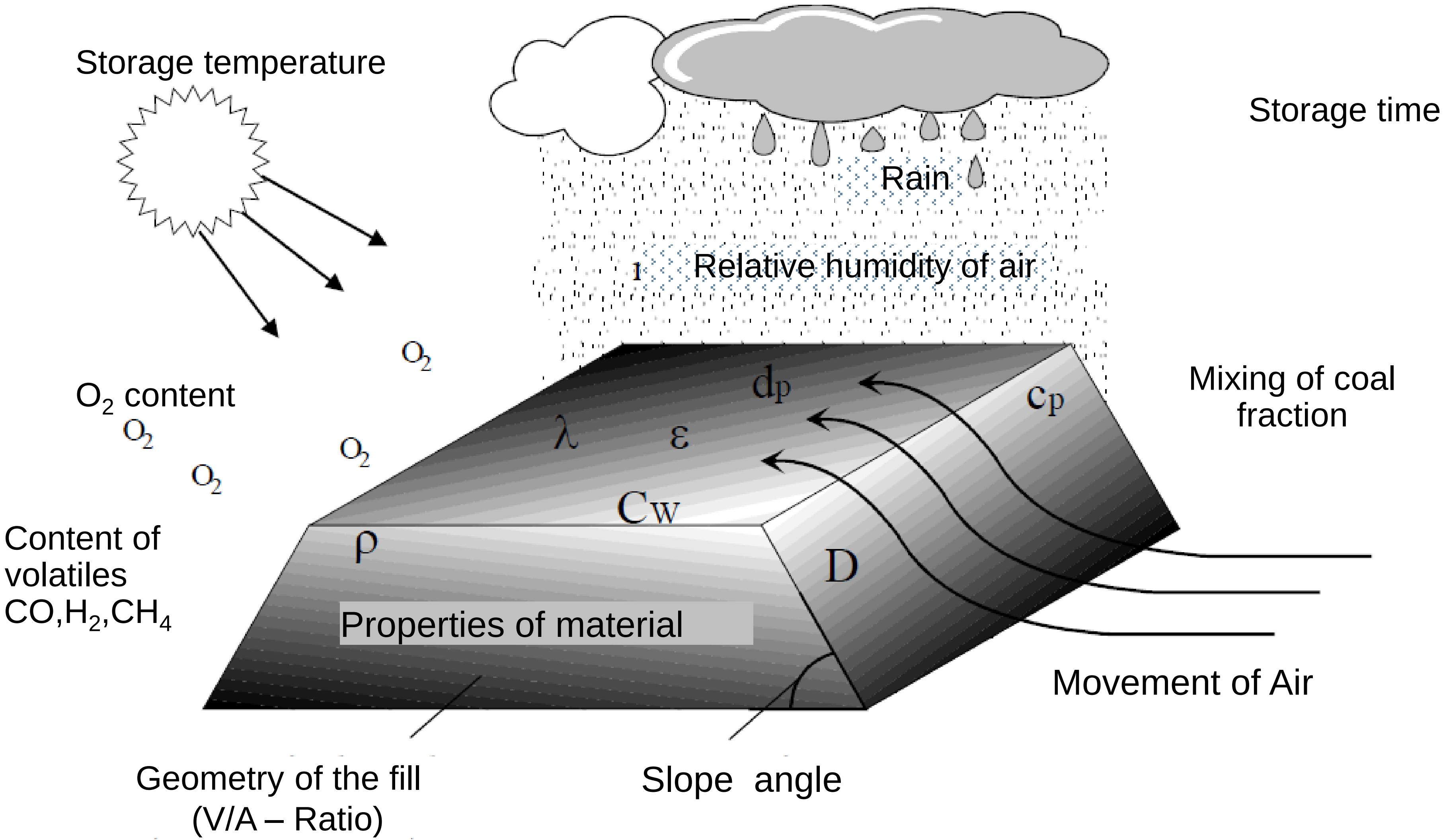
- **Utilization of permissible stress limits of thick-walled components**



- **Start-up with the HP bypass station less open**



Coal Storage
Parameters affecting the self ignition



Coal Storage

Recommendations:

- **Compaction in layers of coal**
- **Build heap side not to steep**
- **Adjustment of the stock pile to main wind direction**
- **Avoidance of water in the stock pile underground**
- **Regular, or as well continuous temperature monitoring**

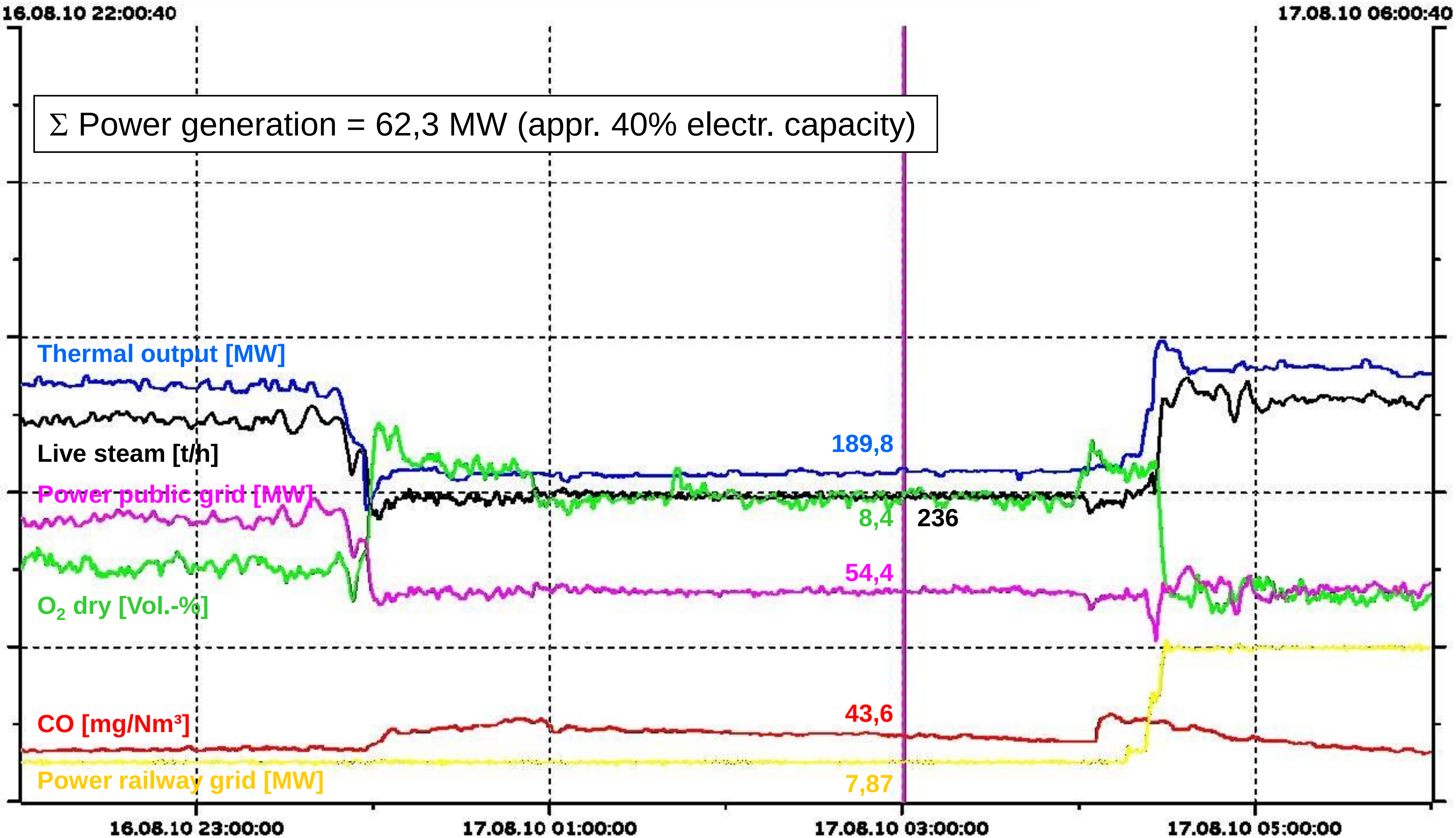
Measurement in case of fire:

- **Clear sections with hot spots (T>50°C)**
- **Spread thin and let it cool down**
- **Do not extinguish with water (s.a.)**

Average Content of volatile: 39,5%(waf)

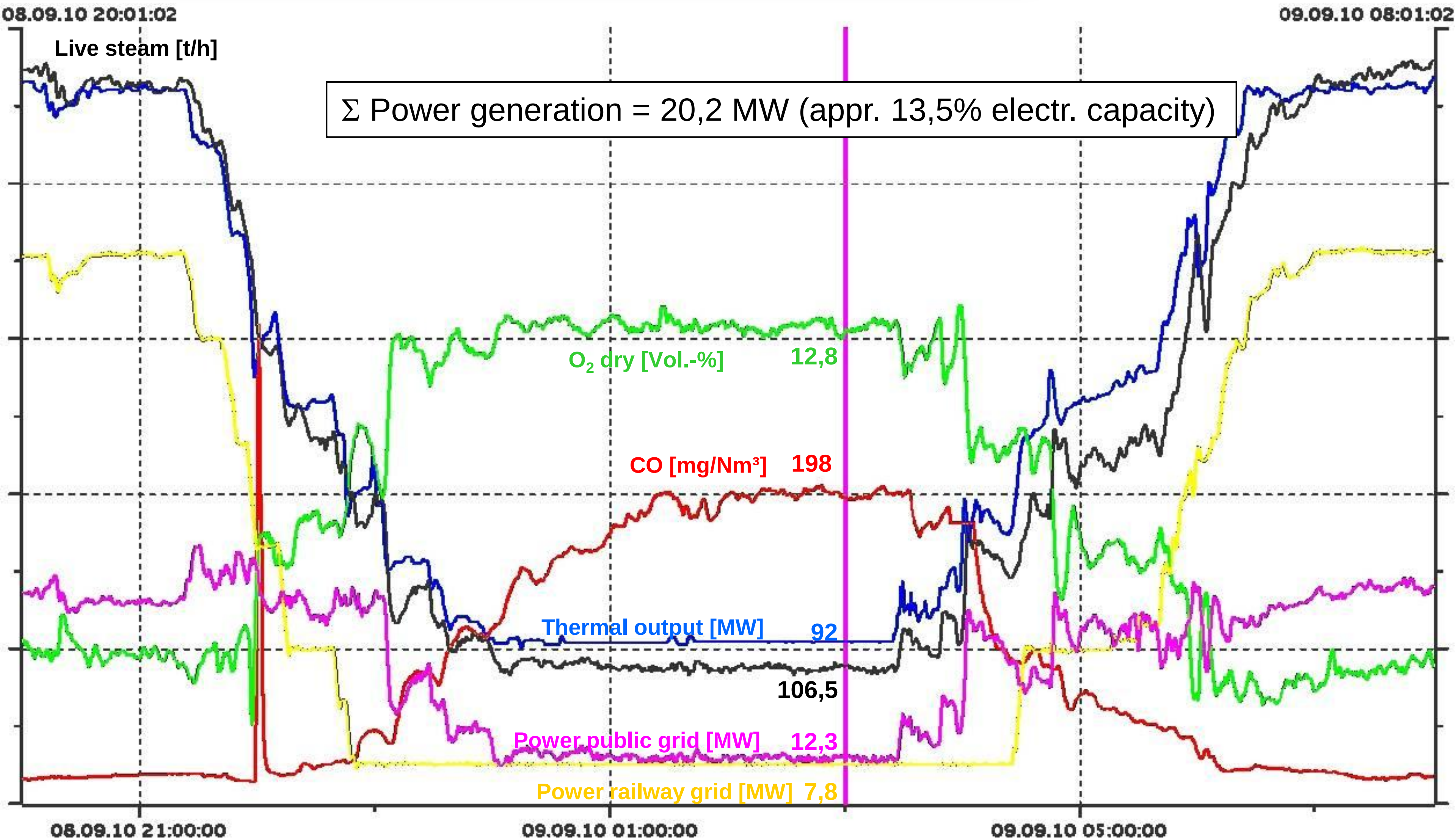
Combustion system

Typical low-load operation of a 150 MW – Unit



Combustion system

Reliable and stable low-load operation with only one burner level



Combustion system

Flame shape during low-load operation

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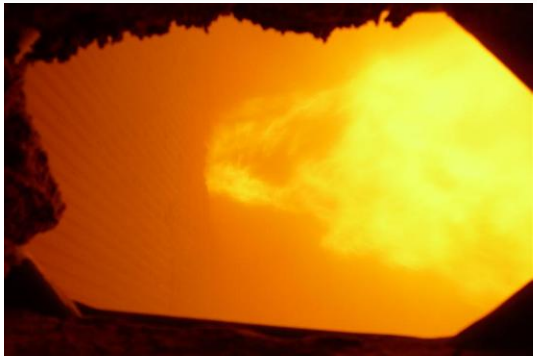
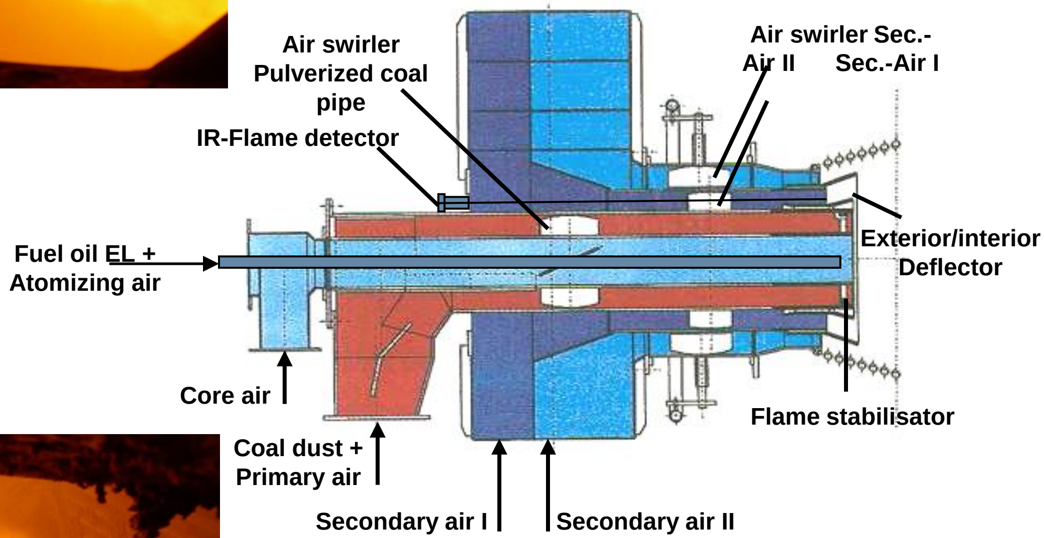
Burner 21



Burner 22

One burner level (< 15% electr. capacity)

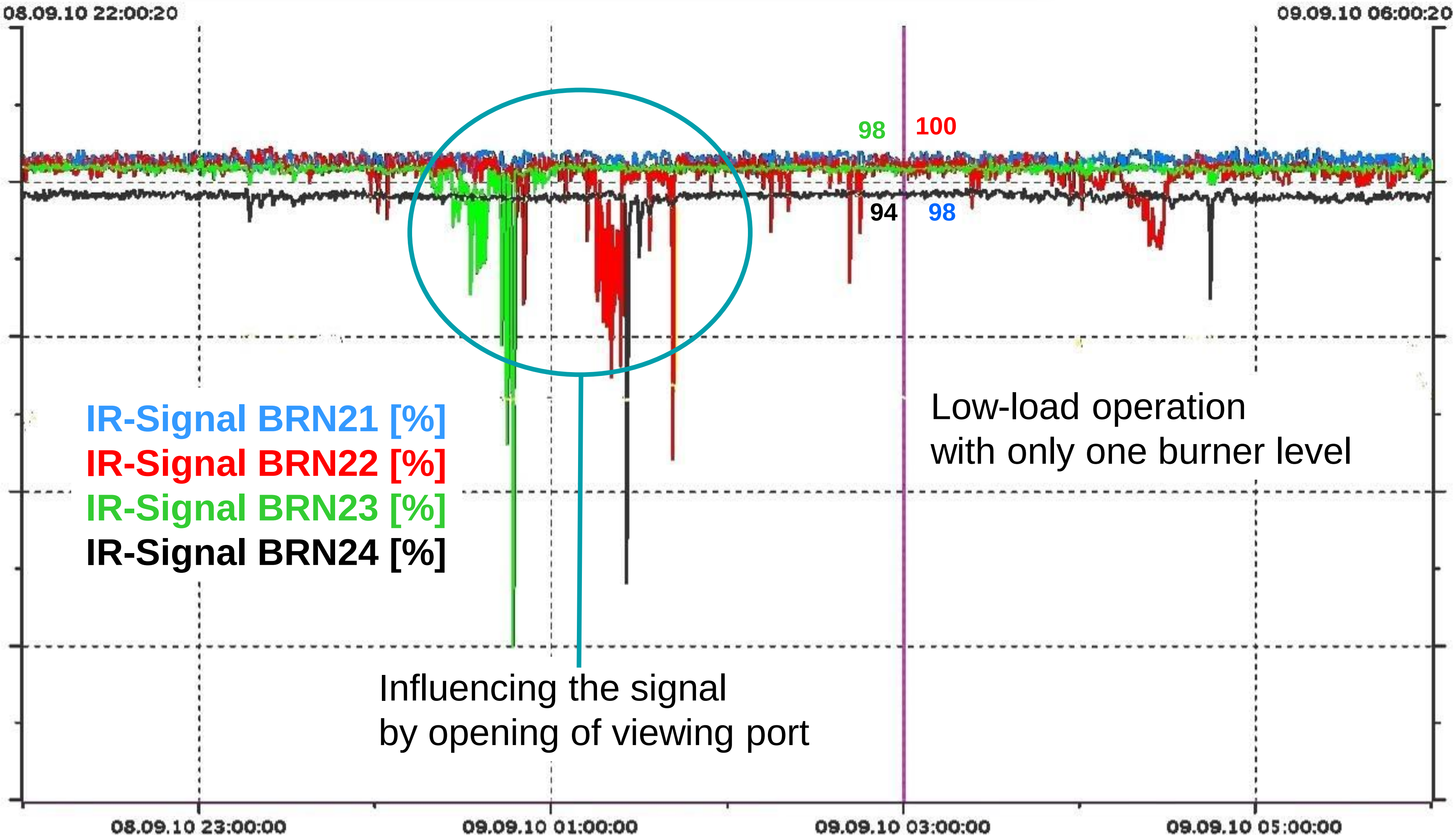


Burner 23

Burner 24

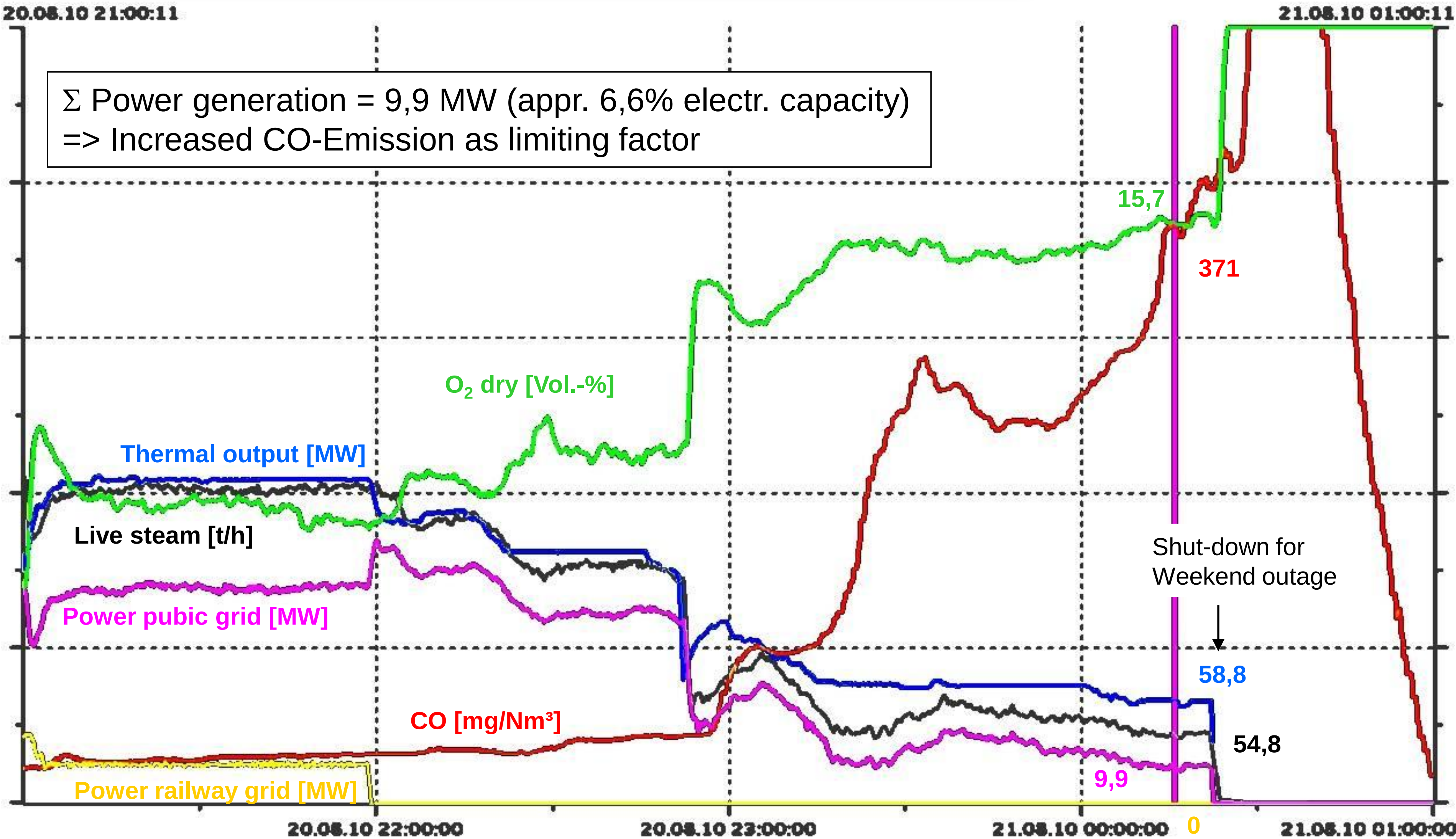
Combustion system

Signals from Flame monitors



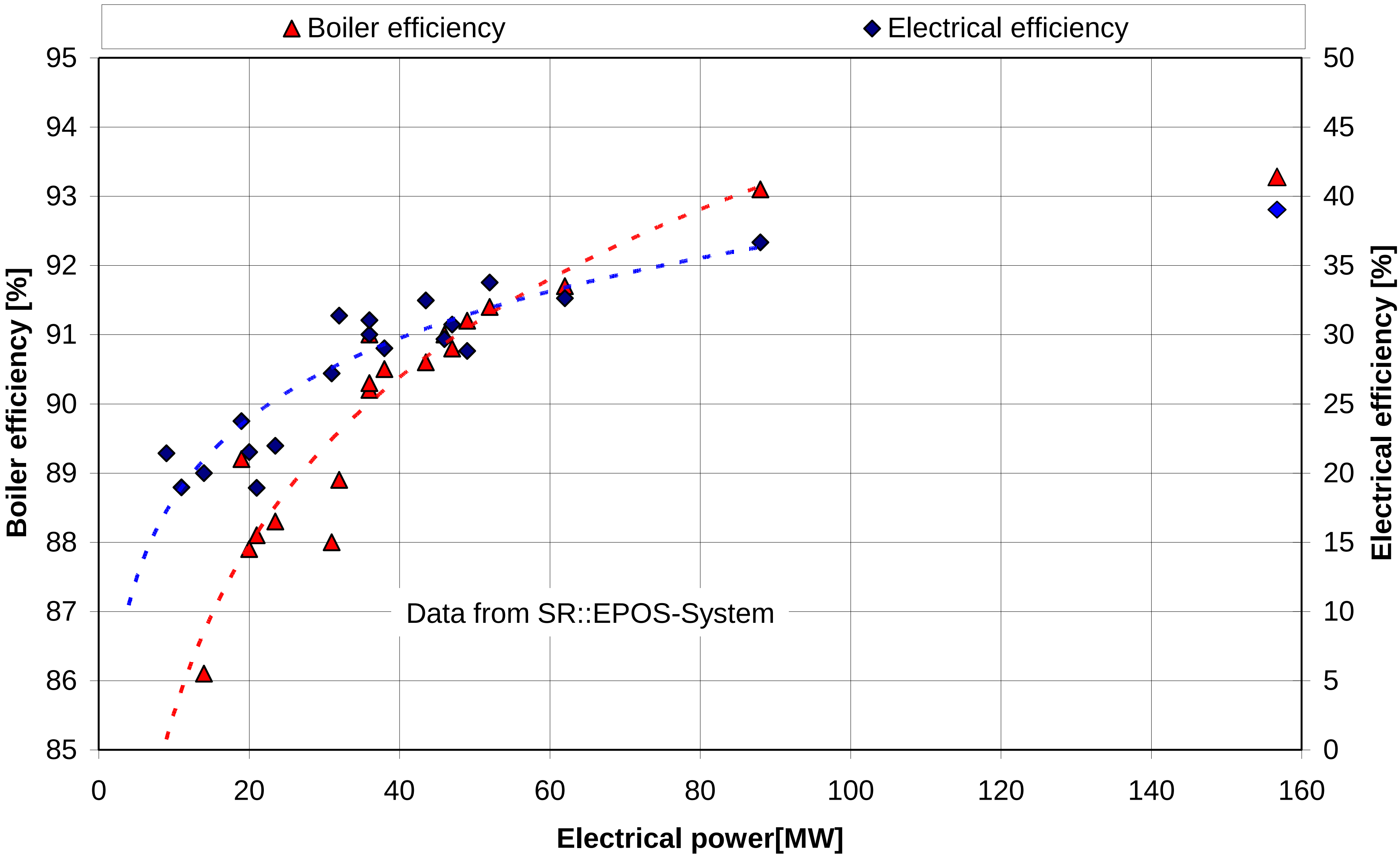
Combustion system

Low-load operation close to electrical auxiliary station requirements

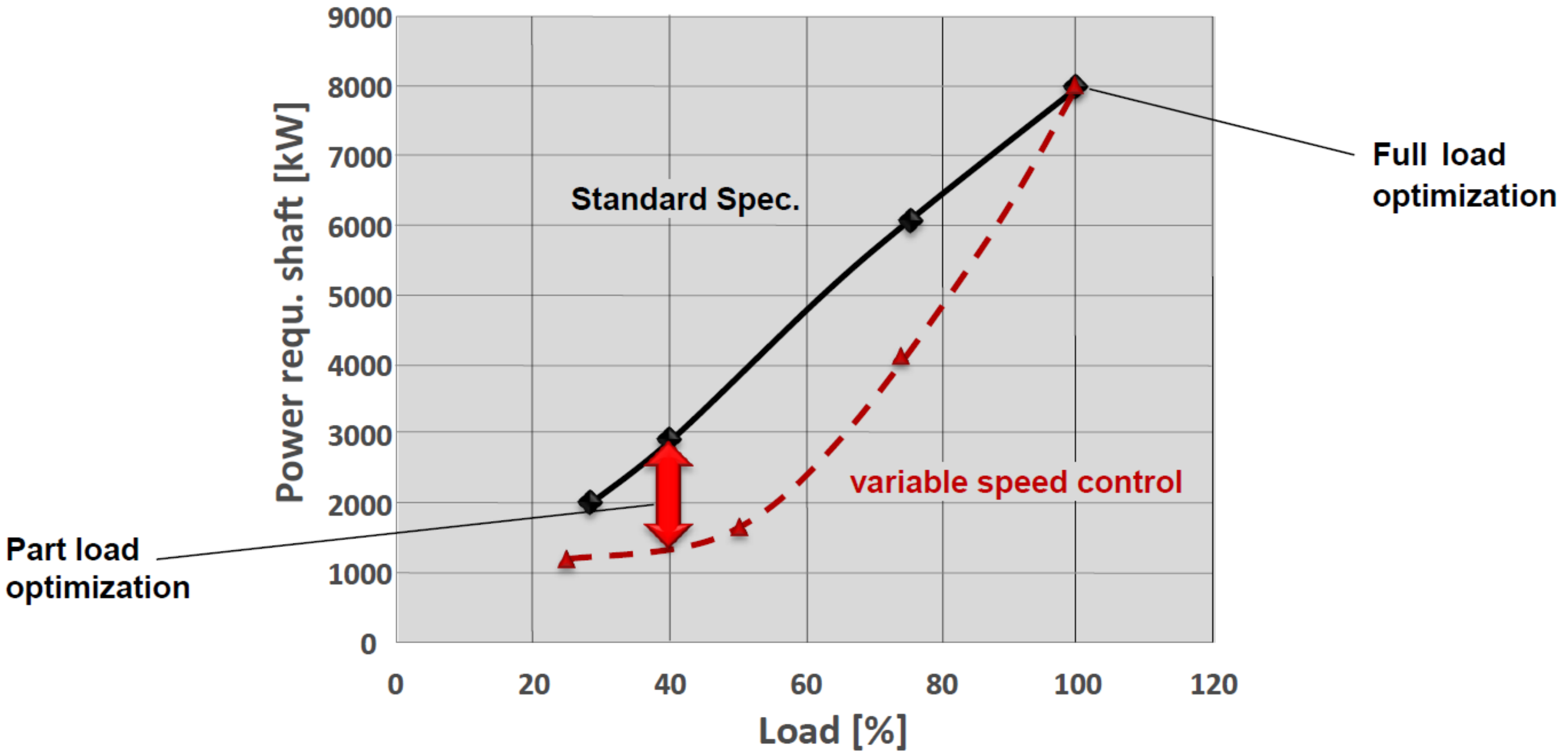


Combustion System

Electrical Efficiency / Boiler Efficiency



Optimization of part load efficiency
Variable speed controls



Example: 800 MW, Efficiency @ 40% Load 40 % (SG: 94,5%)

Σ: + 0,25 % Efficiency @ 40% Part load

Source: Schreier 2011

Combustion System

Optimisation of low-load operation of a 150 MW-Block

Reliable and stable operation at

- < 20% electrical power in 2 - level – operation
- < 15% electrical power in 1 - level – operation

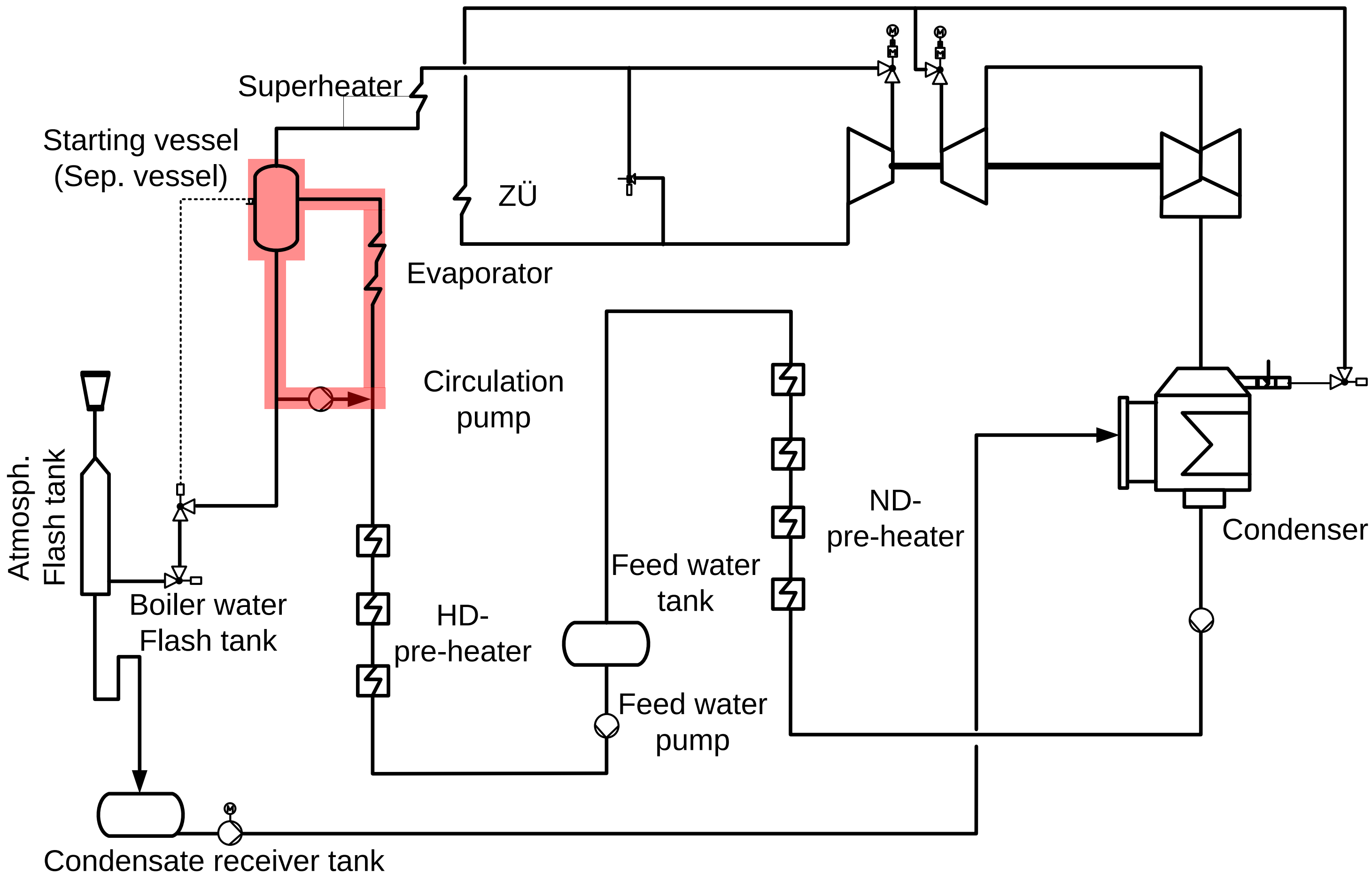
Optimisation of low-load operation by

- Reduction of unnecessary cooling air
- Increase of the turbulence / swirl at the burner

Not the flame monitor signals or stable ignition,
but the CO-Emission determine the lowest low-load operation point

Water Steam Cycle

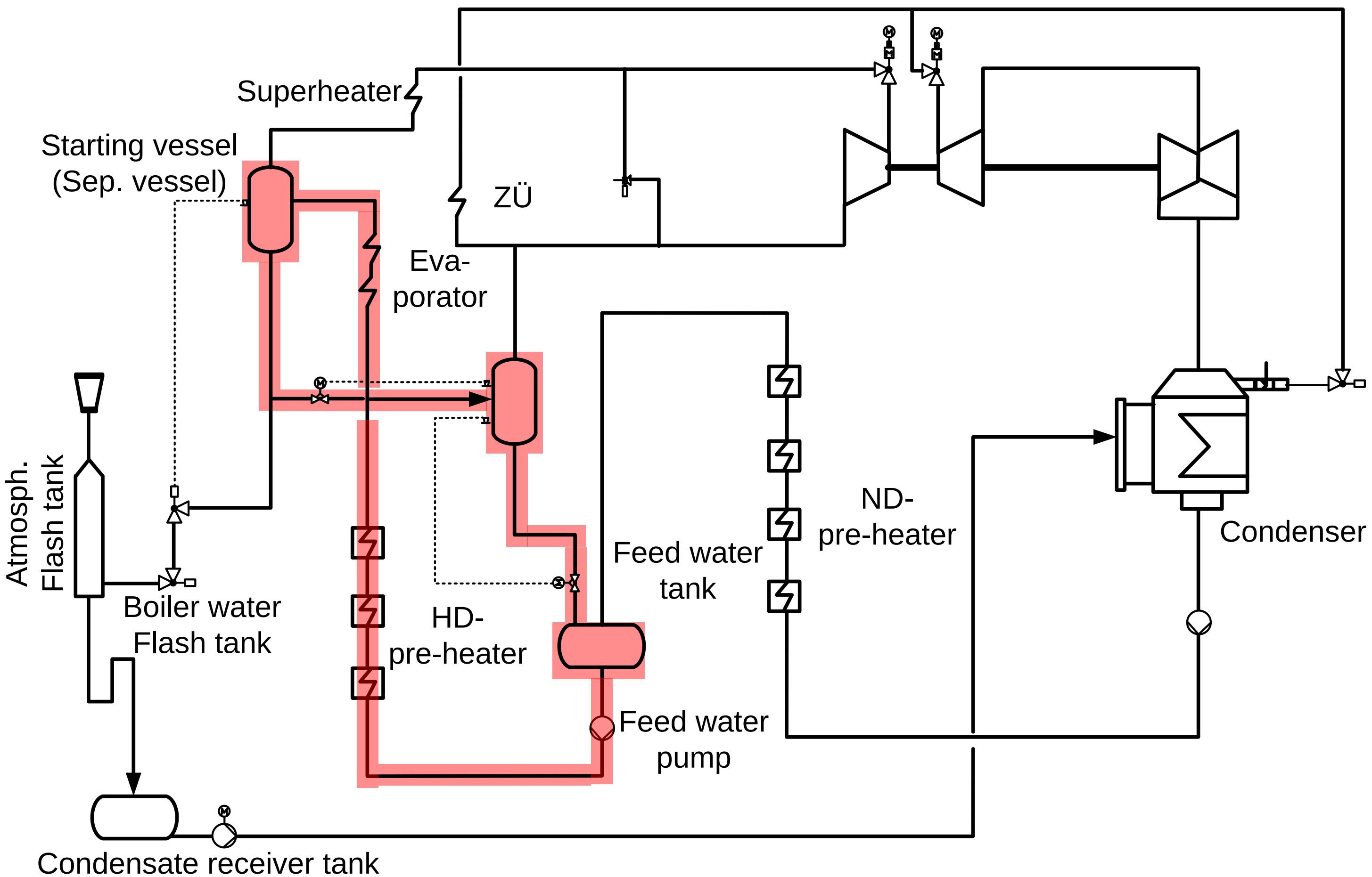
Start-up-/Low-load system with circulation pump



- Heat retains in the cycle
- High investment costs

Water Steam Cycle

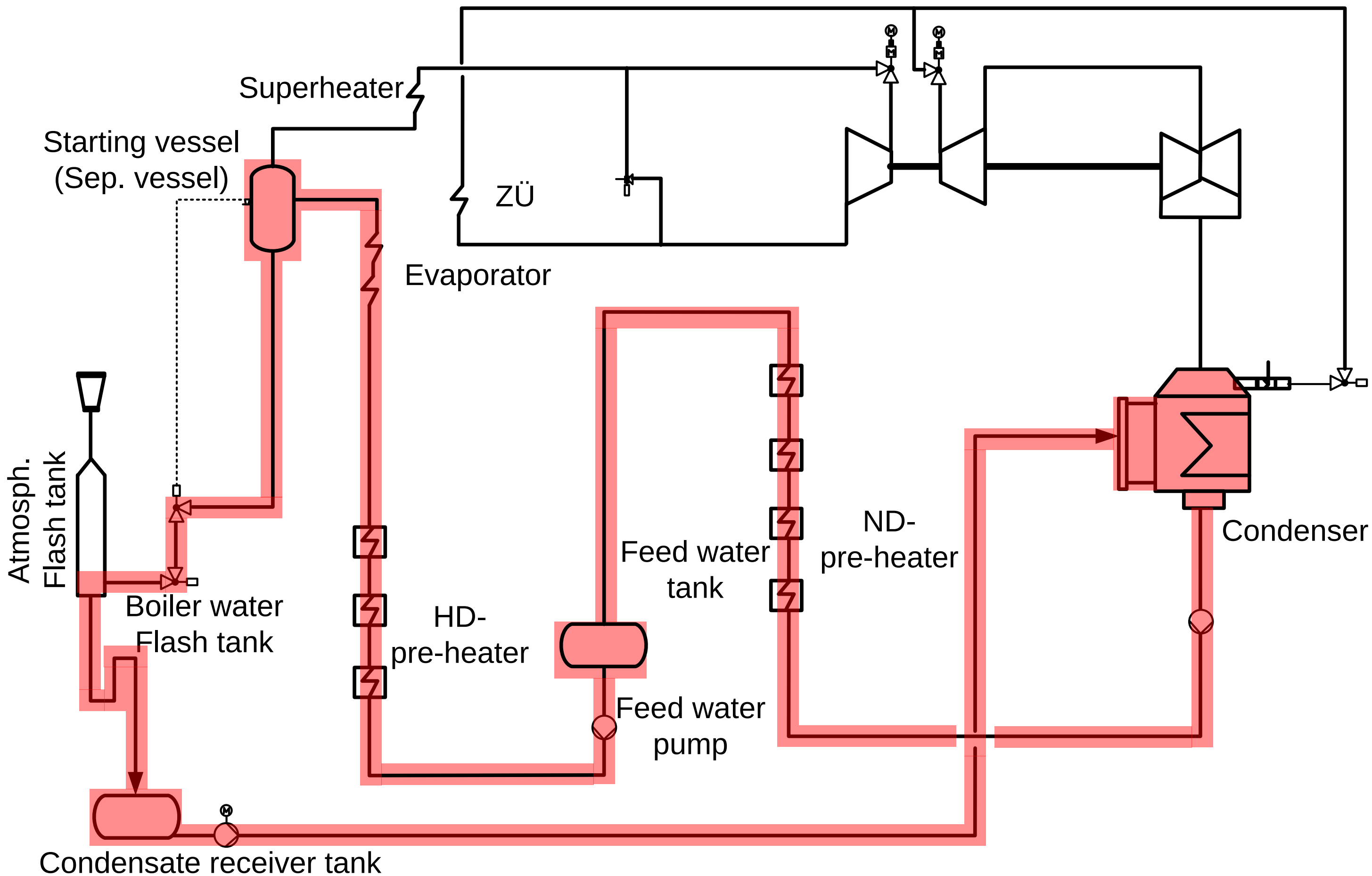
Start-up-/Low-load system with intermediate flash tank



- Heat economy slightly less than with circulation pump
- Lower investment cost in comparison to circulation pump

Water Steam Cycle

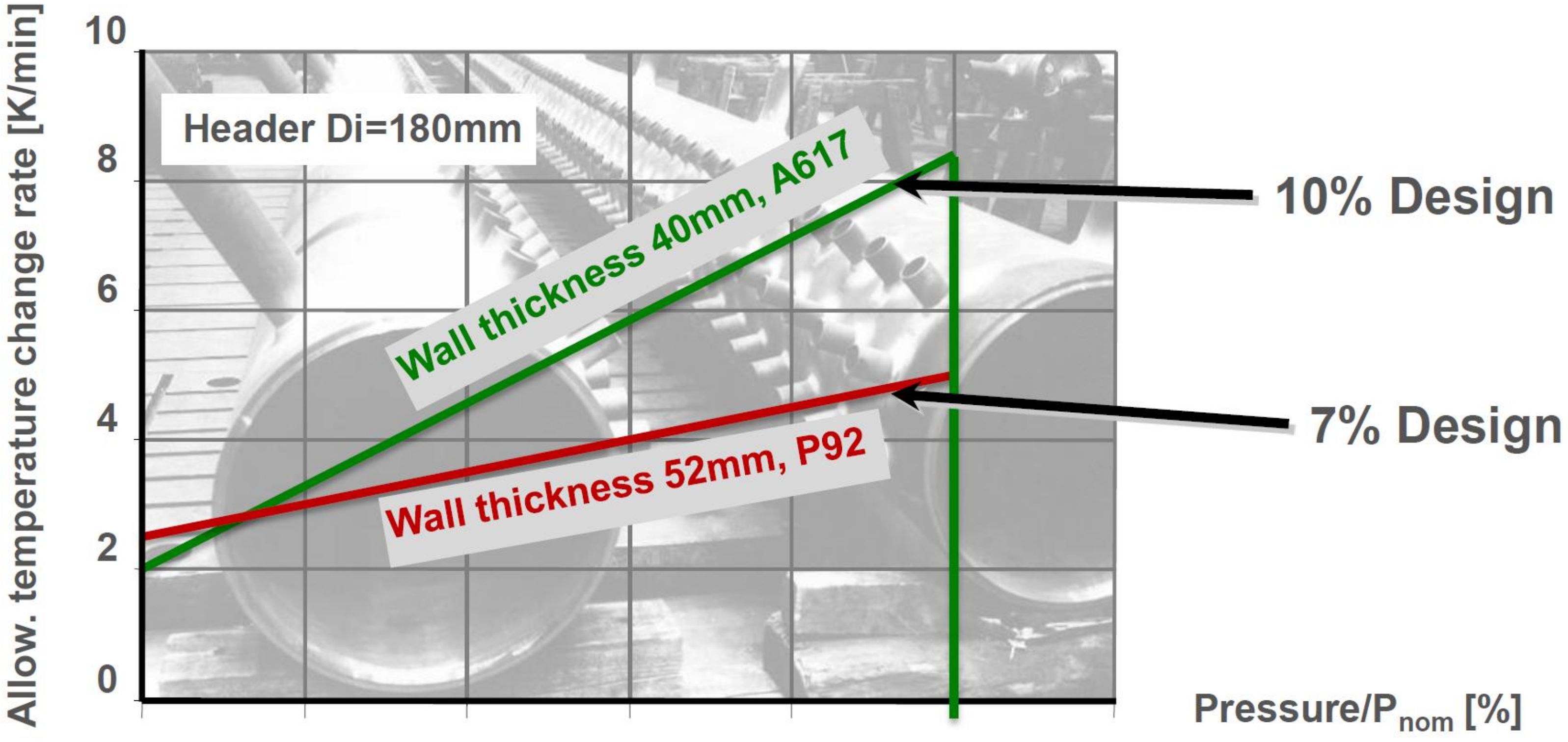
Start-up-/Low-load system with atmospheric flash tank



- Concerning heat economy the worst design
- Very low investment costs

Reduced wall thickness

- 2 line to 4 line design leads to reduction with Factor 0,707 of header wall thickness
- increase the number of separators/ headers
- use of superior materials, e.g. A617 instead of P92

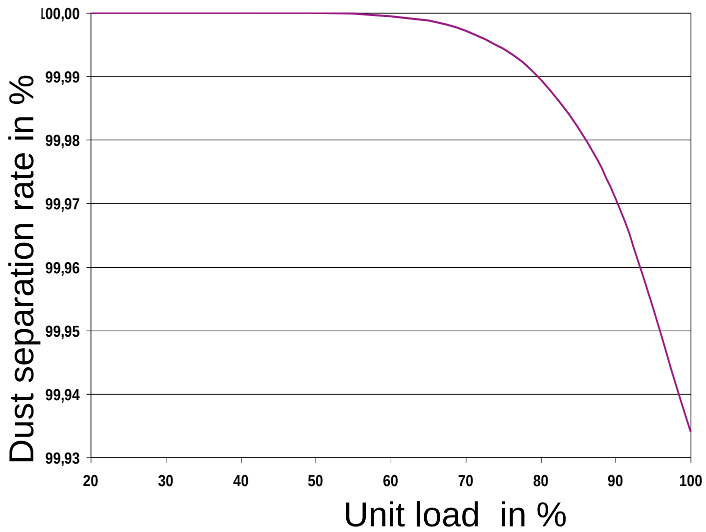


Source: Schreier 2011

ESP

Clean gas dust content acc. to Deutsch: $r = R \cdot e^{-w \cdot \frac{A}{\dot{V}}}$

➡ Exponential influence of the migration velocity w as well as the spec. separation surface A/ $\dot{V}$



Half of the operation volume means

➡ Double of the spec. separation surface

➡ Optimisation of the separation capacity

Not the separation efficiency is limiting the low-load operation, but the insufficient combustion with unburnt carbon

➡ Fraction of unburnt coal particle increases

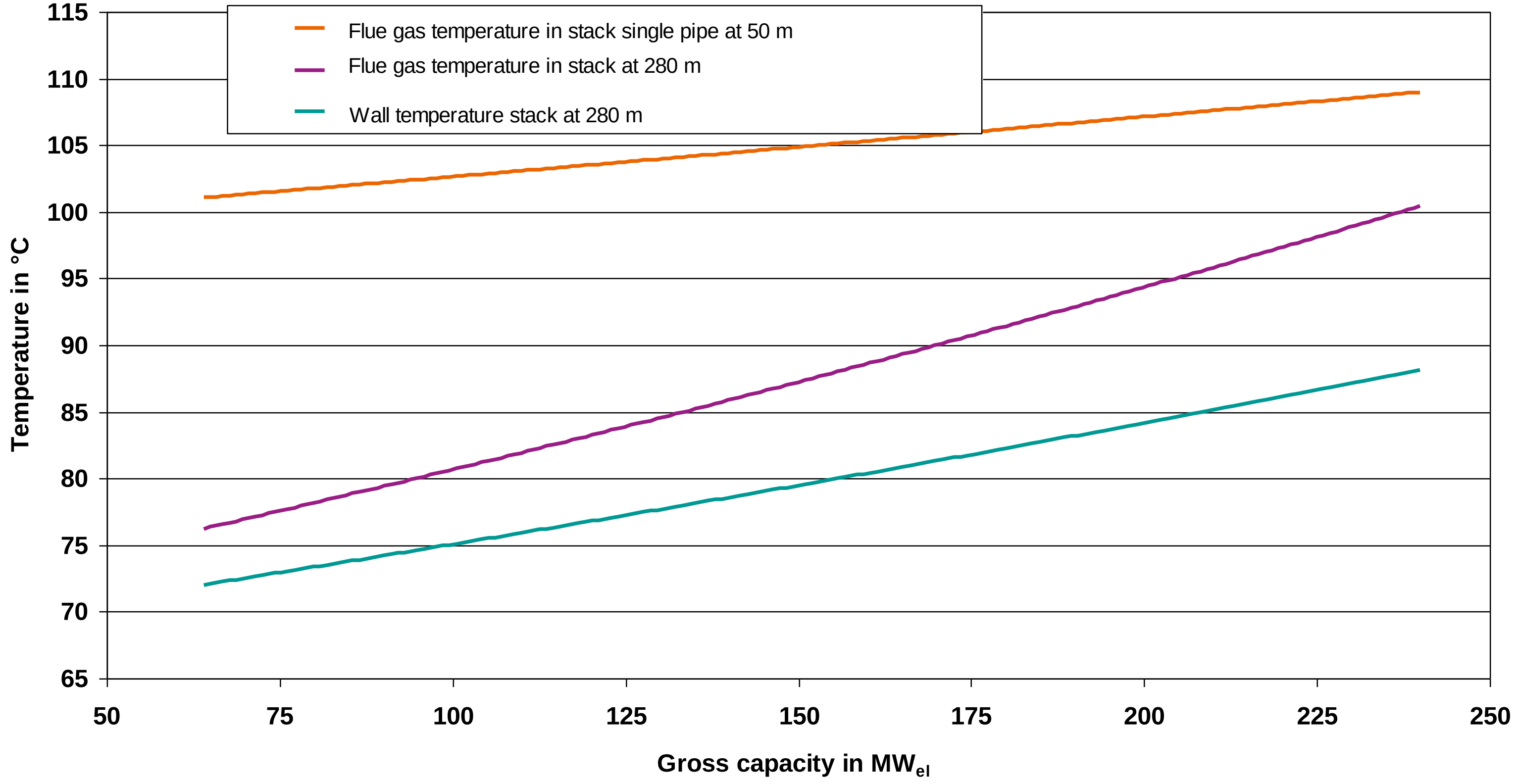
➡ Ash only commercial usable if C-content < 5 %

Flue Gas Desulphurization

Very low flue gas velocity due to low-load operation

- ➡ Reverse flow in the inlet area of the scrubber
- ➡ Increasing slagging at the duct walls
- ➡ Optimisation by insertion of guide vanes or wall injection

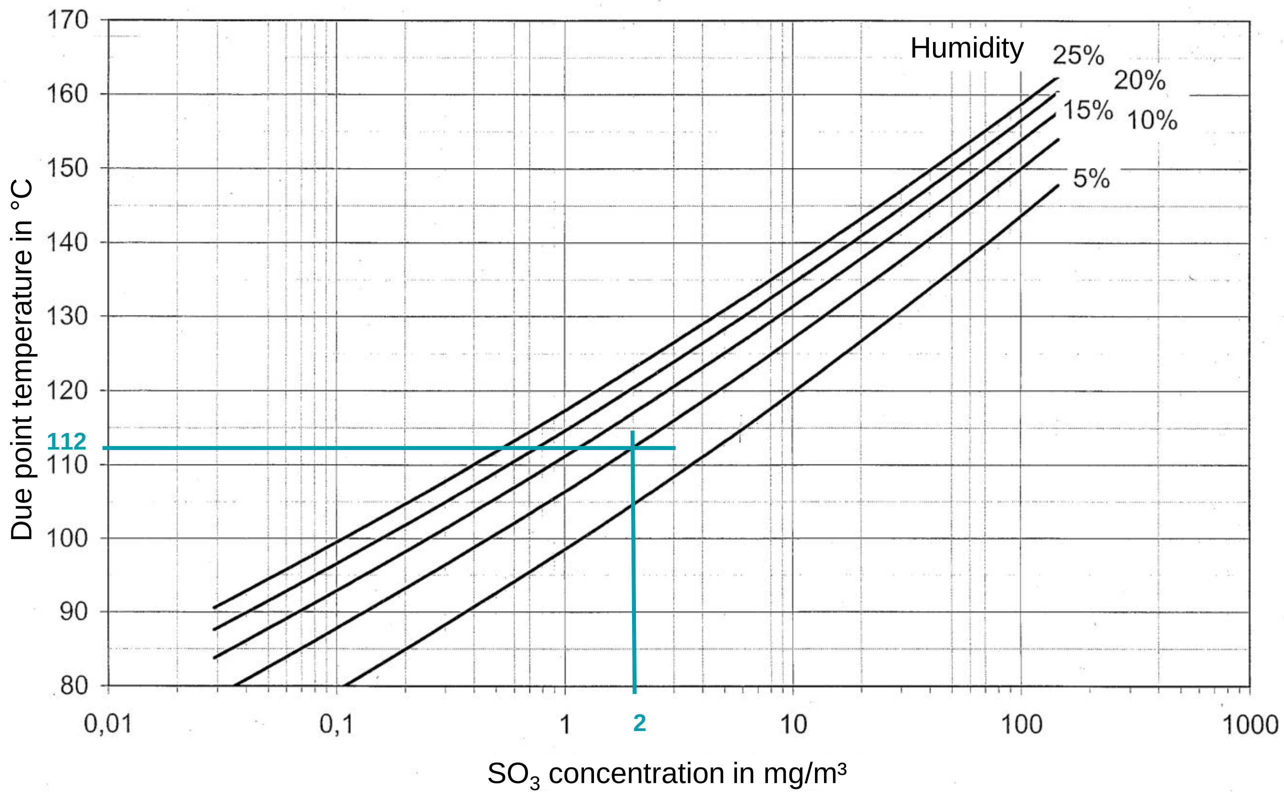
Stack



Lower flow velocity at low-load operation

- longer retention time of flue gas in stack
- higher heat loss of flue gas

Stack



Operation below acid due point due to low-load operation

- Formation of aerosols at small dust particles
- Discharge with the flue gas flow

Stack

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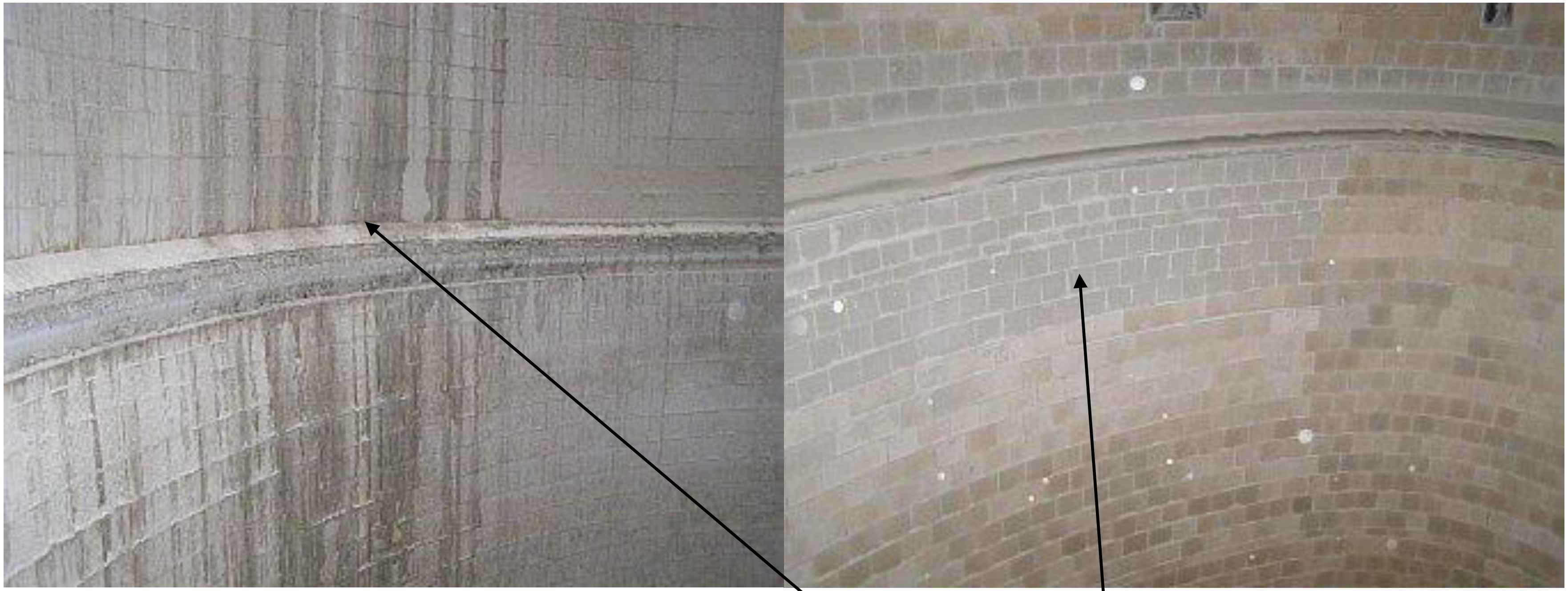


no adhesion at the mansory pipe at appr. 50 m

Traces of condensate at appr. 275 m

Low velocity

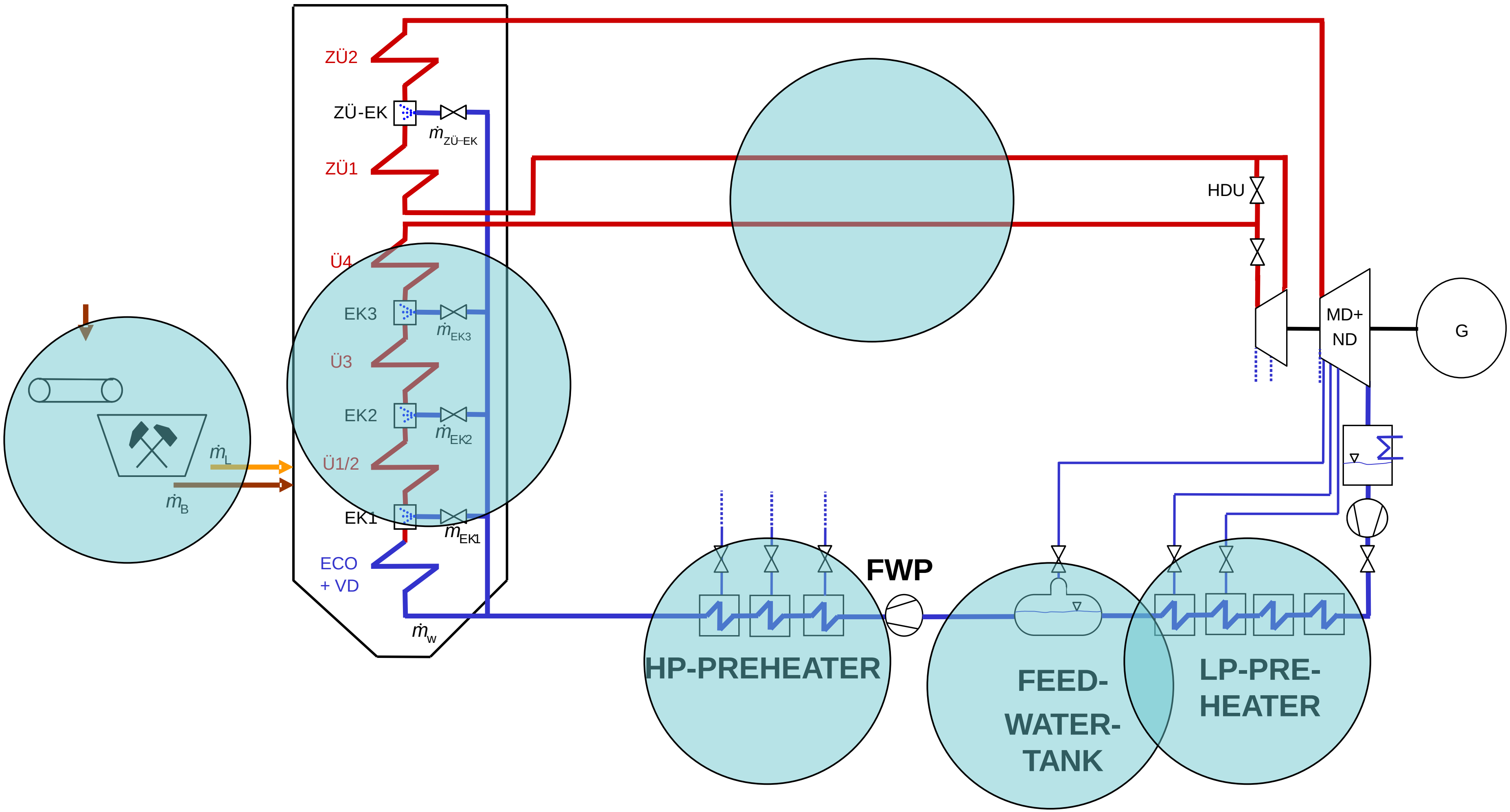
- Weather influence at stack outlet
- Traces of condensate- resp. rain water

Stack


Contamination by fine dust and other products of reactions

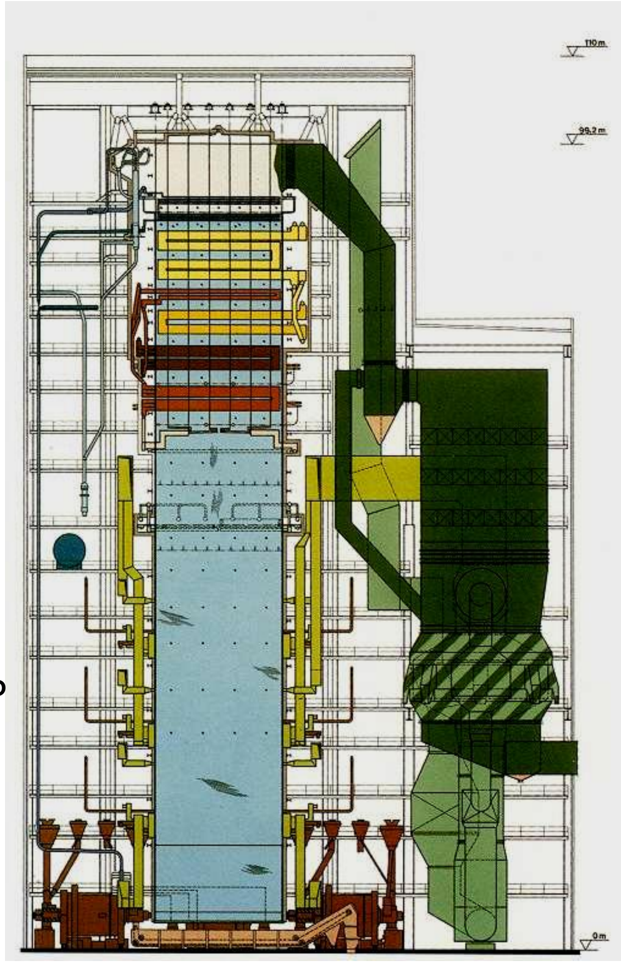
- ➡ Drying-out by temperature changes
- ➡ Slagging and fouling
- ➡ Flake off and discharge of agglomerate particles at load increase

Common use of storage capacities for high unit performance



CHP Herne IV Main Data 1

• **Steam generator**		Benson, tower type
Thermal capacity of boiler	MW	1.277
Steam capacity	t/h	1.584
Life steam temperature	°C	535
Life steam pressure	bar	255
Reheater temperature	°C	541
Reheater pressure	bar	63
Feedwater Temperature	°C	284
• **Mills**		Tube mill
Number		3
Capacity	t/h	85
• **Turbo generator**	One flow HP, Two flow MP, Two Flow LP	
Nominal capacity	MW	383
Generator nominal capacity	MVA	550
Generator nominal voltage	kV	21



CHP Herne IV — Main Data 2

- **Feedwater pumps** — 2 x 50% electrical variable speed

- **Cooling** — Cooling Tower

Cooling tower height	m	132
Cooling tower diameter (ground)	m	88
Water flow	m³/h	37.100

- **Generator transformer**

Nominal capacity	MVA	500
Nominal voltage	kV	21/245

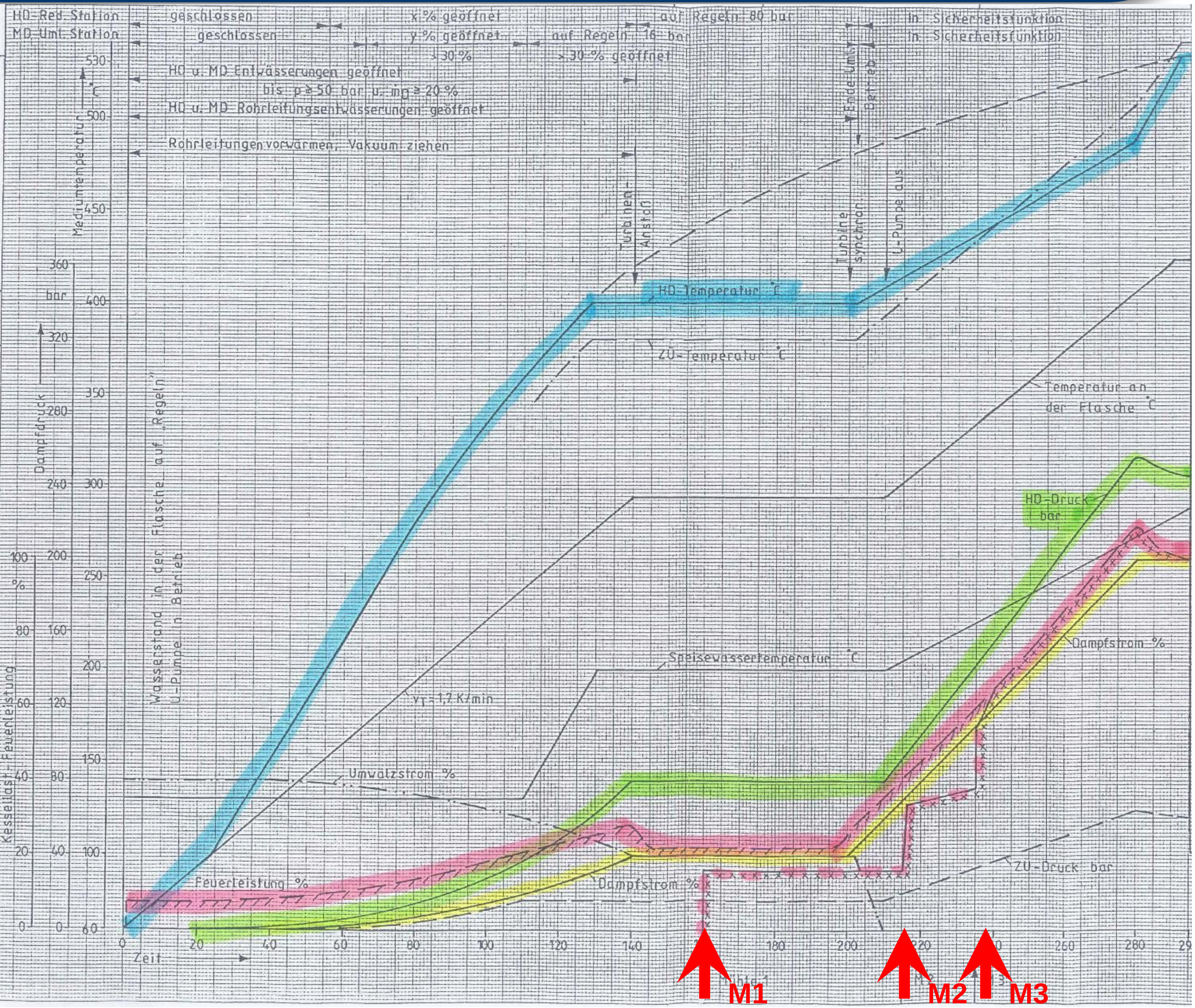
- **Stack**

Height	m	300

- **Flue gas desulfurization plant** — Wet lime scrubbing process

- **NOx reduction plant** — SCR process

Cold Start Up
Herne IV older plot



Kaltstart Kessel
Kaltstart Turbine

Kessel: 0 ÷ 140 min
Turbine: 140 ÷ 295 min
: zeitführend

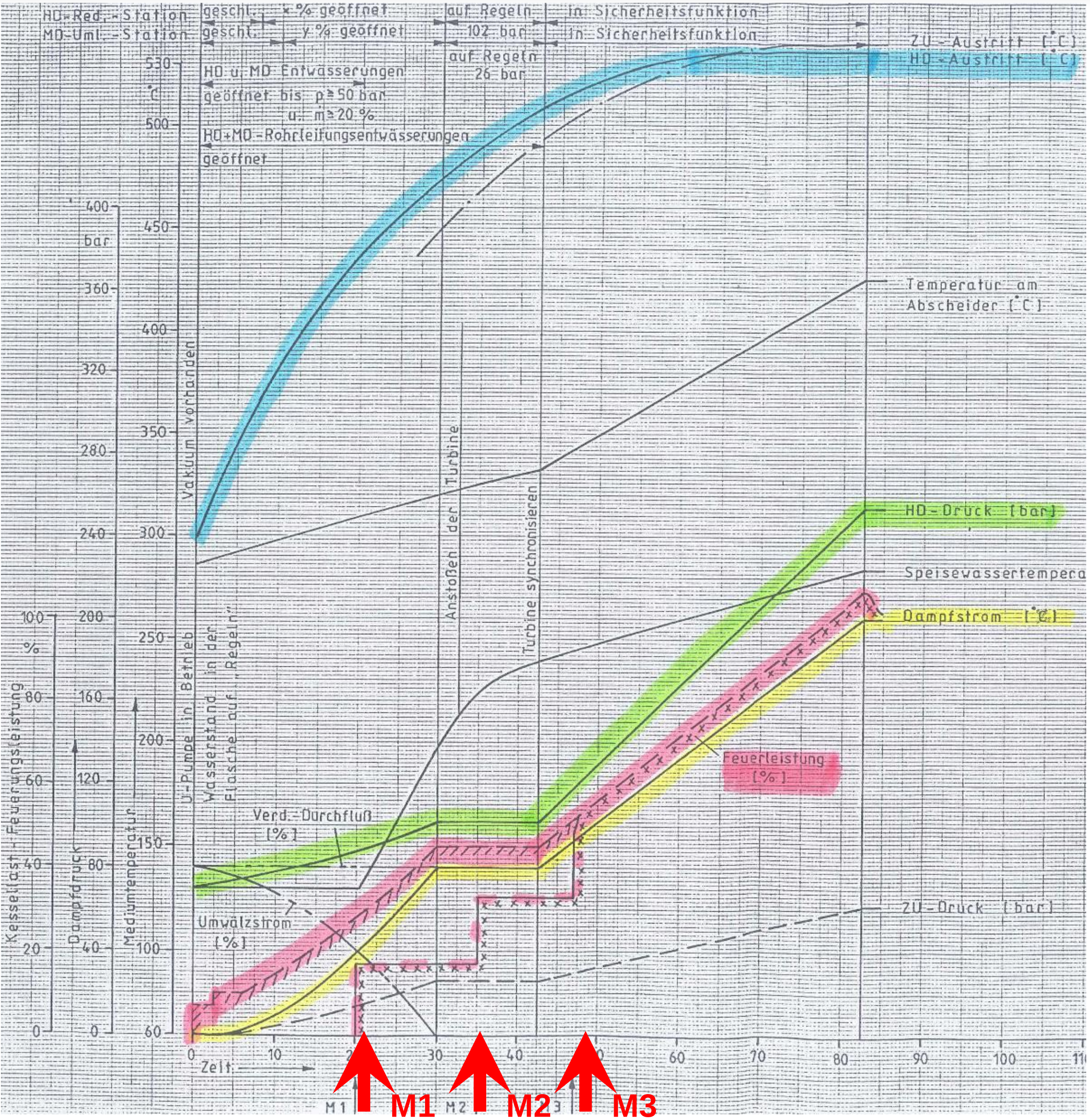
Temp.-Diff. $\Delta\vartheta$ (Grenzwert)
Temp.-Gradient v_ϑ (Richtwert)

		P bar	v_ϑ K/min	$\Delta\vartheta$ K
Kessel	HD	0	2,4	
		254	5,8	
	ZÜ	0	5,4	-26,5
		62	8,1	-39,5
Rohrleitg.	HD	0	2,58	
		254	3,45	
	ZÜ	0	4,0	
		62	4,62	
HD-Red.-Stat.				
Turbine	HD			
	ND			

Turbinen-Forderungen:

1. Dampf z. Vakuum ziehen und Stopfbuchsendampf
2. Dampfzustand b. Turbinenstart:
   HD 400 °C 80 bar
   ZÜ 380 °C 16 bar
3. Synchronisierung:
   HD 400 °C 80 bar
   ZÜ 380 °C 16 bar

Hot Start Up



Warmstart nach 8 h

Kessel: 0 ÷ 30 min
Turbine: 30 ÷ 100 min
Rohrltg: zeitführend

Temp.-Diff. Δϑ (Grenzwert)
Temp.-Gradient v_{ϑ} (Richtwert)

		p bar	v_{ϑ} K/min	Δϑ K
Kessel	HD	0	2,4	
		254	5,8	
	ZÜ	0	5,4	-26,5
		62	8,1	-39,5
Rohrleitg.	HD	0	2,58	
		254	3,45	
	ZÜ	0	4,0	
		62	4,62	
HD-Red.-Stat.				
Turbine	HD			
	ND			

Turbinen-Forderungen:

1. Dampf z. Vakuum ziehen und Stopfbuchsendampf
2. Dampfzustand b. Turbinenstart:
   HD 470 °C 102 bar
   ZÜ 450 °C 26 bar
3. Synchronisierung:
   HD
   ZÜ

Turbinenvollast nach 100 Minuten

Summary

- Hard coal fired power stations of Steag had been operated in the past already in mid merit order, world wide base load is typical
- The current challenges of the “ Energiewende” are asking for further improvement of the technology, due to the increasing part of renewable energy conventional power plants will have frequent outages and need higher ramp rates
- All components of the power plant are highly stressed by the new kind of operation
- With increasing low-load operation high amounts of coal remain at the coal storage over a longer period with the risk of self ignition
- The combustion system must be able to offer high flame stability also at low load without support fuel
- Decreasing HP and IP temperatures accompanied by too high gradients can lead to ineligible stresses of the casings. Low overheating can lead to erosion effects by droplets in the turbine
- As well the entire flue gas pass is affected

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